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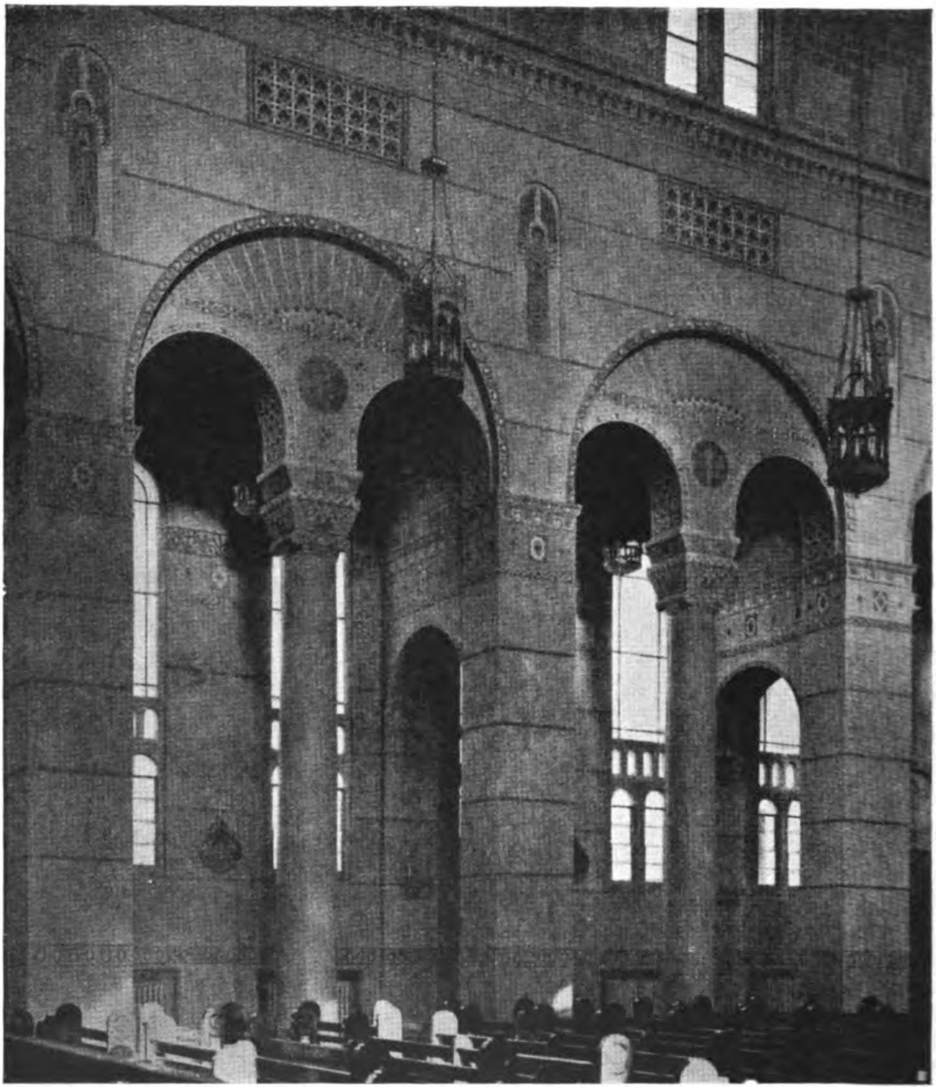
WILMINGTON,
HULL.



[*Messrs. Murphy & Elmsted, Architects.*

CHURCH OF THE SACRED HEART, WASHINGTON. (*See p.* 23.)

[The walls from the floor to the top of the cornice are of concrete, the decorative patterns being obtained by the use of coloured aggregates for the surface.]

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIX. No. 1. LONDON, JANUARY, 1924.

EDITORIAL NOTES.

THE FLOOR COLLAPSE AT PLAISTOW.

ONCE more the daily press has come out with headlines such as "Two Men Killed in Fall of Concrete Floor," "Concrete Floor Collapse" and all the subtle variations known to the sub-editor by which a headline can be made arresting enough to induce the public to read an item of news such as the unfortunate accident at Plaistow, by which two men lost their lives, just before Christmas. It is to be regretted, however, that in thus ably performing his duty to the newspapers by drawing attention to the news of the day he should unwittingly be doing harm to another great industry. The accident at Plaistow is a case in point. Were the full facts known when the first news was published it is probable that the obvious conclusion to be drawn from the affair would have led to very different headlines being used: as an item of news it was simply a collapse of a concrete floor, but the facts as brought out at the inquest show that concrete as a material was not to blame. Mr. M. W. Hudson, a Building Inspector of the West Ham Borough Council, in giving evidence at the inquest is reported as having said that "He visited the building a fortnight previously and the concrete floor was not then laid. After the accident he went to the place and found that one bay and part of a second one of the concrete of the first floor had fallen down. The material which had fallen was in a sodden and disintegrated condition, and it was not thoroughly set. In his opinion the construction of the floor was faulty. The rods reinforcing the concrete were not properly fixed. They simply lapped over the top edge of the flange of the girders instead of being hooked or anchored, and the concrete was not supported from the bottom of the girders. If he had seen this work he would certainly not have passed it. The contractor should have given him notice that he was about to begin to work, but he had not done so. Screened clinker and cement was not the proper stuff to use for a concrete floor. [An operative on the work, in evidence, had stated that the concrete was composed of cement and screened clinker in the proportion of about 1 : 7.] The testing of the strength of a concrete floor should be made by loading the floor. The supports of this concrete had been removed too soon. Mr. Chicken [the builder, who was one of those killed in the accident] was a keen man of business and took great interest in his work. The witness could only suggest that he had a lack of technical knowledge of this particular class of work." In reply to a question by the Coroner, the witness stated that the work had not been scamped, " but it had not been carried out in a proper manner." It is to be regretted that, except in the case of a very few newspapers, the report of the inquest, when given at all, was not given as great a prominence as the first report of the accident, and that a large proportion of the public was given the impression that reinforced concrete as a material was to blame, whereas the failure was solely due to the fact that, in the words of the Coroner, the builder " had not sufficient technical skill and knowledge for this class of work."

The Secretary of the Club for which the work was being carried out stated that the builder had " undertaken the erection of this addition to the Club and had superintended the work," so that apparently no architect or engineer was consulted as to the design of the work. Had such been the case it would have been practically impossible for such an accident to have happened, and the fact that it did occur is a strong argument in favour of consulting an expert before such works are undertaken. This unfortunate accident also points to the need for educating all connected with concrete construction on the elementary principles of reinforced concrete design, such as are given in a handy and easily understood form in our new publication, " The Concrete Year Book," of which further particulars are given on p. 52.

CONCRETE IN ARCHITECTURE.

In this issue we give some examples of developments in the architectural treatment of concrete. The two churches, one in America and one in France, are particularly interesting in view of the motives of the architects—in the first case there was apparently no incentive to the strictest economy, and concrete was chosen as the material of construction simply because the architects considered it to be the best material for the purpose ; in the second case, after carefully studying the relative costs of different materials, concrete was selected solely on its merits as the cheapest material. The methods of treating concrete surfaces by exposing the aggregate, developed by Mr. John J. Earley, have been adopted in the American church, and, although the colour effects cannot be appreciated from the half-tone illustrations, we are told by critics who have seen this building that the results are very pleasing indeed. Another interesting feature of this church is the carved concrete figures on the interior of the walls. We have before expressed our belief in the future of textural treatments of concrete surfaces, and welcome this example as an indication that the architectural profession is realizing the possibilities presented by concrete of obtaining pleasing effects and at the same time economizing in material.

Concrete is now passing through a period of evolution ; having been accepted as the best and cheapest material for most modern building requirements, the æsthetic side of the question is now being studied. This process of evolution is common to all methods of building and all building materials : first they are adopted to cover the requirements of the barest necessities alone, artistic considerations coming afterwards. It is therefore very gratifying to see that reinforced concrete has been accepted as a complete building material for such a fine structure as the Church of the Sacred Heart at Washington, and that the first real attempt has been made to treat the surface of concrete so that the most critical taste is satisfied without the expenditure of a considerable sum of money in covering with marble or natural stone the walls of a building which is already structurally sound. Such a building will undoubtedly be the forerunner of others, and it is to be regretted that there is no example in this country of a monumental building in which these methods have been employed. We are confident, however, that when the architectural profession in this country realizes the possibilities of treating concrete surfaces it will not be long before similar buildings are erected here. The argument in their favour is not solely one of economy, for an infinite variety of blends of colour may be obtained by the judicious selection of aggregates.

We also illustrate in this issue a number of examples of cement-stucco finishes to which colour and interest are given by the use of coloured sands and the individuality of the plasterer. These methods, although applicable to all classes of buildings, seem particularly suited for smaller cottages, and the great variety of colours and finishes in which cement-stucco can be carried out by these methods should be specially useful to those seeking means of avoiding monotony in large housing schemes.

CONCRETE ROAD SURFACES.

In view of the criticism sometimes seen in trade and other journals with regard to the wearing properties of reinforced concrete roads, and statements such as we recently saw in a motoring paper that traffic " skids all over the place " on a bare concrete road, the following abstract from " Roads and Road Construction " is of considerable interest : " In view of the controversy occasioned by our criticism of the very haphazard way in which, unfortunately, many concrete roads are made, we have during the past month made a point of visiting various concrete roads where the surfaces have not been covered with carpets of any description, saving here and there with a painting of either tar, cold mix or silicate of soda. The conclusion at which we have arrived is no different to that which we have already published, namely : that a concrete road without a surface of any other material is entirely satisfactory provided great care is taken in mixing, depositing

Concrete-Block Hospital in Africa.

[Other illustrations of this hospital, which is the largest in Africa, were given in our last issue.]

and curing. From the point of view of motorists of all classes, that is to say, users of either heavy or light vehicles, the hard smooth surface provided by a concrete road is probably nearer the ideal than any other type of road. There are many districts requiring a road of somewhat greater strength than that provided either by tar macadam or bituminous mixtures laid on the top of ordinary water bound macadam, and which yet cannot afford the expense of a concrete foundation with a bituminous carpet. It is in such cases as this that the entire concrete road fills the need. Such well known engineers as Mr. Harrison, of Southwark, and Mr. Robinson, of Surrey, have given this type of road their most careful attention, and they have learnt much from the failures and partial successes of other prominent engineers, including themselves. Mr. Harrison conducted us over various concrete streets he had laid, taking us over those which he regarded as failures first of all and explaining to us the cause of failure. He has now acquired such a thorough knowledge of the construction of this type of road that he informed us he will not hesitate to use it extensively in the future. Mr. Harrison is very satisfied with silicate of soda for surface treatment. With regard to Mr. Robinson's roads laid in Surrey, through the whole length we could discover no serious flaw, in fact we may say in truth no flaw whatever, though several miles of them have been open to moderately heavy traffic for over six months." The Editor of our contemporary has seen the roads and formed his own opinion, and one wonders whether the statements so often to be seen in other journals would be published if their accuracy were first investigated at first-hand. A recent issue of a motoring contemporary, for instance, contained a letter which seems to indicate that a large number of motorists do not always recognize a concrete road when they see one, for a correspondent stated that " at the top of Alconbury Hill I found an Enfield rider had slid ten yards on the grease at the corner, whilst cars of all sorts either crawled round or slid about in a terrifying manner. I subsequently found it impossible to ride up Alconbury Hill in safety except on low gear." After such an experience it is no wonder our contemporary's correspondent condemns the surface of Alconbury Hill, but as in doing so he condemns all " new concrete road surfaces " and derides the " much vaunted non-skid properties of this [the concrete] road," it may not be out of place to state that Alconbury Hill is not a concrete-surface road at all, but consists of part concrete and part macadam foundation entirely covered with a carpet of asphalte.

ANOTHER CONCRETE BRIDGE OVER THE THAMES.

PLANS have been passed by the Thames Conservancy for the erection of a new bridge over the Thames, by the Reading Corporation, to replace the existing Caversham Bridge. The plans provide for a reinforced concrete structure in two spans, one of 126 ft. 4 in. with a headway of 15 ft., and one of 106 ft. 4½ in. with a headway of 12 ft. 8 in. The reinforced concrete bridge recently built across the Thames was illustrated and described in our issue for November, 1923.

It is also announced that the suspension bridge across the Menai Straits is to be replaced by a reinforced concrete structure.

STRUCTURAL STEEL-WORK REINFORCED WITH CONCRETE.*

By EWART S. ANDREWS, B.Sc., A.M.Inst.C.E., M.I.Struct.E.

CANADIAN EXPERIMENTS ON BEAMS.

As Mr. Singleton Green was good enough to point out in his letter in the September issue, particulars were published in *Engineering News Record* for May 3 and June 28 last of a report by Professors Mackay, Gillespie, and Lelnan of tests made for the steel fabricators' section of the Canadian Manufacturers' Association on the strength of steel beams encased in concrete. These appeared in this country just after my article was written, and as they give very useful information on the point with which I was dealing, a somewhat detailed account and analysis of these tests will probably be of interest to readers of *Concrete and Constructional Engineering*. Fuller particulars of the tests were given in the *Canadian Engineer*, to which reference has been made in preparing the following notes.

In these tests a steel frame was made of 10-in. I-beams of 16-ft. span supported 5 ft. apart on 24 I-beams, the general arrangement being as indicated in the plan in *Fig.* 1; this frame was tested, and the stresses and deflections at the underside of the flange were measured by means of extensometers at loads corresponding to 75 lbs. and 185 lbs. per sq. ft. of floor area; these test results agreed very well with the values calculated by the ordinary beam theory.

A reinforced floor slab of 1 : 2 : 4 concrete was then cast on the beams together with a casing, the section of the concrete and steel being as indicated in the section in *Fig.* 1.

The dead weight of the joists and concrete was practically equal to the 75 lbs. per sq. ft. for which the stresses in the steel alone had been found by test, and it was found that the stress in the steel due to the dead weight of the concrete was practically the same as for the test load on the steel itself, the slight

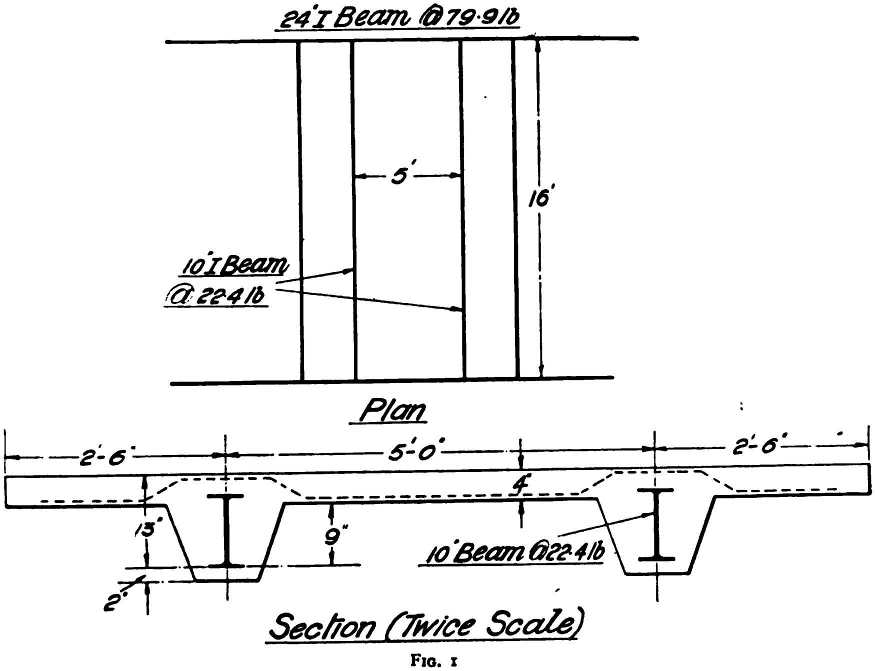


FIG. 1

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* *Continued from August*, 1923.

increase being accounted for by the weight of the formwork.

This seems to bring out the interesting fact that there is no compression stress in the concrete due to its own weight, and the authors of the report suggest that this gives an advantage for structural steel sections encased in concrete as compared with ordinary reinforced concrete construction.

The load of 185 lbs. per sq. ft. for which the steel frame alone was tested corresponded to a dead load of 75 lbs. per sq. ft. and a superimposed load of 110 lbs. per sq. ft.; the measured stress in the steel at this load was 15,500 lbs. per sq. in. (almost exactly equal to the calculated stress), so that according to the ordinary method of designing steelwork the safe load on the floor would be 110 lbs. per sq. ft.

TEST RESULTS ON ENCASED BEAMS.

In the tests on the encased beams, the stresses at the underside of the steel beams were again measured by means of extensometers; the loads were uniformly distributed and took the form of lengths of I-beams laid transversely, the loads being applied to the concrete slabs at points which would develop a reverse bending moment in the slabs over the beams of $\frac{Wl}{12}$.

The results may be summarised as follows :—

Superimposed Load (lbs. per sq. ft.).		Inclusive Load (lbs. per sq. ft.).		Stress in Beam (lbs. per sq. in.).
110	..	185	..	9,530
165	..	240	..	11,880
220	..	295	..	14,380
365	..	440	..	21,500

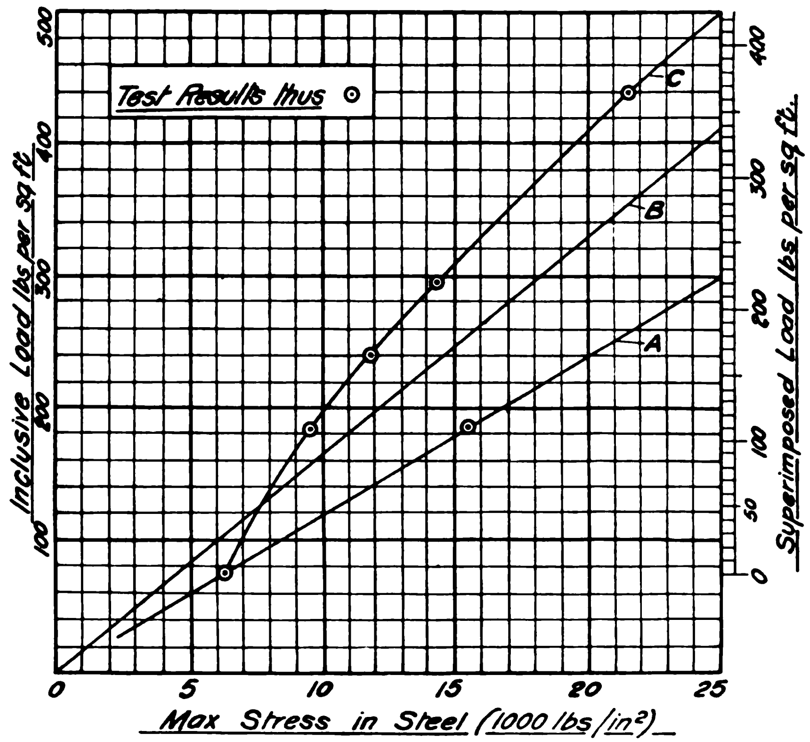

FIG. 2.

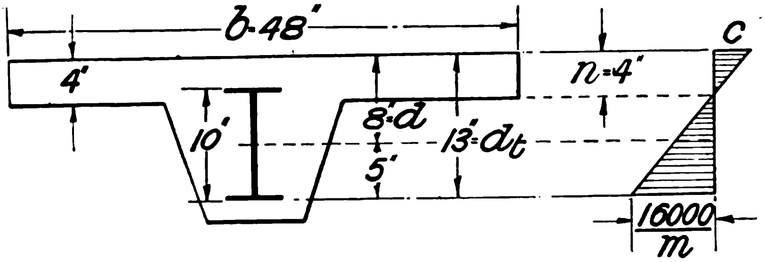

FIG. 3.

These results are shown in diagrammatic form in *Fig.* 2.

Line B represents the result of calculating as a reinforced concrete T-beam with large section reinforcement by the usual theory which will be explained later.

From curve C, which gives the test results, we deduce that in order to develop a tension stress of 16,000 lbs. per sq. in. an inclusive load of 330 lbs. per sq. ft., or a superimposed load of 255 lbs. per sq. ft., would be required.

This means that a floor designed as ordinary plain steelwork to carry 110 lbs. per sq. ft. with a working stress of 16,000 lbs. per sq. in. required a superimposed load of 255 lbs. per sq. ft. (2·3 times as much) to develop that stress. At the inclusive load of 440 lbs. per sq. ft. there was a slight hair-cracking at the bottom of the beam casing, one or two cracks extending to near the bottom of the slab.

In order to test the floor against dynamic forces, a concrete mixer was placed on the floor and run at a " good " speed for two days, but no vibration effects were noticed although the bending moment produced by the mixer corresponded to a superimposed load of 115 lbs. per sq. ft.

CALCULATION AS A REINFORCED CONCRETE T-BEAM WITH LARGE SECTION REINFORCEMENT.

As calculations of reinforced concrete T-beams with large section reinforcement are not very common, it may be of interest to give the manner in which the section in question would be calculated according to the usual theory for this case. (*See Fig.* 3.)

The 10-in. I-beam employed appears to have been that listed in some of the American handbooks as having the following properties :—

Area = 6·5 sq. in.
Moment of inertia = 114 in. units.
Section modulus = 22·8 in. units.

Assuming that the breadth to be taken as a reinforced concrete T-beam is 12 times the slab thickness, i.e., $b = 48$ in., to calculate the depth (d) of the neutral axis we apply the rule that the first moment of the compressed concrete area about the neutral axis must be the same as the first moment of the area (mA) equivalent to the steel acting at its centre.

This gives

$$\frac{bn^2}{2} = mA(d - n)$$

$$\text{or } 24n^2 = 15 \times 6{\cdot}5(d - n)$$

$$\text{i.e. } 24n^2 + 97{\cdot}8n - 828 = 0$$

$$\text{i.e. } n^2 + 4{\cdot}075n - 34{\cdot}5 = 0$$

This is the familiar quadratic equation and gives

$$n = 4{\cdot}2 \text{ in.}$$

The graphs given in most text-books on reinforced concrete for the position of the neutral axis for various percentages of reinforcement can be used by noting that

$$bd = 48 \times 8 = 384.$$

$$\therefore \ \% \text{ reinforcement} = p = \frac{6{\cdot}5 \times 100}{384} = 1{\cdot}69.$$

This graph gives $\frac{n}{d} = {\cdot}5$ approximately for $p = 1{\cdot}69$, so that we have

$$n = {\cdot}5 \times 8 = 4 \text{ in.}$$

As 4 in. is the depth which brings us just to the bottom of the slab, we will take this value for the remainder of the calculation.

The stress in the steel varies in the manner indicated in *Fig.* 3, and the concrete stress c corresponding to 16,000 lbs. per sq. in. in the steel is given by

$$c = \frac{16000}{m} \times \frac{n}{13 - n}$$
$$= \frac{16000}{15} \times \frac{4}{9}$$
$$= 475 \text{ lbs. per sq. in.}$$

We next proceed to find the equivalent moment of inertia of the section about the neutral axis, remembering that if I is the moment of inertia of an area A about an axis passing through its centroid, the moment of inertia about a parallel axis at distance x from it is given by the quantity $I + Ax^2$.

We then have:

Equivalent moment of inertia about neutral axis

$$= I_E = \frac{bn^3}{3} + m\{I + A(d - n)^2\}$$
$$= \frac{48 \times 4^3}{3} + 15(114 + 6{\cdot}5 \times 4^2)$$
$$= 4294 \text{ inch units.}$$

$\therefore$ Equivalent tension modulus of section

$$= M_T = \frac{I_E}{15(13 - 4)} = \frac{4294}{135} = 31{\cdot}8 \text{ in. units.}$$

This is the figure which is to be compared with the section modulus of 22·8 in. units for the steel beam alone.

The span was 16 ft., so that the weight W to produce a stress of 16,000 lbs. per sq. in. in the steel is given by

$$\frac{Wl}{8} = 16{,}000\, M_T$$

$$\text{i.e. } W = \frac{16000 \times 31{\cdot}8 \times 8}{16 \times 12} = 21{,}200 \text{ lbs.}$$

$$\text{i.e. weight per sq. ft.} = \frac{21200}{5 \times 16} = 265 \text{ lbs.}$$

approx.

On comparing the results of this treatment as shown by line B in *Fig.* 2 with the test results as shown by curve C, it is clear that the test results are higher and that the strengthening effect of the concrete progressively comes into action as the loading increases.

If we made a similar calculation to the above on the assumption that the effective breadth of the reinforced concrete beam was the full distance of the **I**-beams apart, viz., 60 in., we should find that the calculated weight per ft. to produce a stress of 16,000 lbs. per sq. in. in the steel would be considerably below the test value, and we are therefore driven to the conclusion that the increase of strength found on test is in part due to the tensile resistance of the concrete.

It would have been very interesting if the tests could have been continued until the yield point in the steel had been passed; in this case we should expect the test curve C to curve back to meet the line B, because the concrete would then have developed sufficient tension cracks to have destroyed the additional strength due to tension in the concrete.

AN ARCHITECTS' AND SURVEYORS' POCKET DIARY.

Last year the first edition of the Architects' and Surveyors' Pocket Diary (published by the Architects' and Surveyors' Assistants' Professional Union, 36 Victoria Street, S.W.1; price 2*s*. 6*d*. net) met with a large measure of success, and as the 1924 edition has been considerably improved, both in text and binding, it may be anticipated that the demand for it will be even greater this year. In addition to the diary, which is in the convenient form of one opening to a week, and the usual data and information to be found in diaries, there is a mass of useful information of everyday use to those concerned in building, including notes on fire insurance, mensuration, the preparation of drawings for local authorities, the new British Standard Sections, and memoranda relating to all the separate building trades. The book is of convenient size, and although it contains nearly 200 pages it is only ½-in. thick.

SECONDARY STRESSES IN REINFORCED CONCRETE ARCHED BRIDGES.

By W. L. SCOTT, A.M.Inst.C.E.

Of the many bridges throughout the country about to be constructed at the present time, reinforced concrete is being adopted for an increasing number. This is undoubtedly due as much to advantages obtainable with this material as it is to the higher percentage of local unskilled labour employable than with steel or masonry bridges.

These advantages are patent to all engineers having a knowledge of this material, and with the large number of examples now available in all parts of the world, interested authorities are able as a result to regard reinforced concrete bridge construction as without any doubt beyond the experimental stage. Furthermore, many of the structures actually built or about to be built are of considerable span, and for such cases where reinforced concrete is employed it is usually found that bridges of the arch type are most suitable for adoption.

So far as the construction of reinforced concrete structures of all types is concerned, it is generally agreed that this country can hold its own, and the writer, after inspecting work in this country, France, and America, considers this opinion fully justified. Methods of construction in this country are held by our French friends to be somewhat conservative, and some of the works treated by us as of a temporary nature would, on the Continent, in many cases be almost suitable for permanent work. The American contractor usually expresses surprise at the rather old-fashioned methods employed in Britain as against the utilisation of every labour-saving device employed in the United States.

Apart from the question of whether these views are justified or not, or whether our methods of construction may be changed for the better, the fact remains that reinforced concrete construction in this country compares very favourably in respect to quality with that in any other country.

With regard to the design of reinforced concrete bridges, however, it is doubtful whether the practice in this country is as far advanced as that on the Continent, particularly in France. French engineers in the past few years have designed and successfully constructed a number of very fine reinforced concrete bridges, remarkable for their size and comparative lightness, and these bridges are undoubtedly the result of the close study given to the various internal and external forces of all kinds coming upon the structure. The effect of these forces having been investigated and determined, provision is made in the design either in the strength of the member subjected to them or alternatively by introducing devices which eliminate or neutralise them. Particularly is this the case with hingeless arches.

The majority of the older text books on the subject assume the maximum stresses induced in a hingeless arch bridge member to be produced by the worst combination of permanent and superimposed loading with the maximum assumed variations of temperature. In practical fact, however, there are three additional factors that are of the greatest importance, not so much on account of their individual magnitude but rather because they are cumulative in effect.

Moreover, the deformation in the arch rib produced by these factors is identical in form with that produced by a drop in temperature. The stress resultant from the latter atmospheric variation is thereby increased. For the probable atmospheric variation of temperature affecting arch bridge design it is customary to assume a figure of 30° Fahr. above and below normal. Whilst there may be some justification for criticism of this figure as being too great in the case of a rise of temperature, a drop of temperature of 30° from the assumed normal figure may well be reached in any part of the country, and it may in some localities be exceeded.

The cumulative result of these effects is equivalent to a shortening of the arch member or members, thereby causing the arch to flatten at the crown. This arch shortening with consequent flattening is not merely a theoretical consideration, but actually occurs in the work; and if evidence of this is required periodical inspection of an arch bridge in which expansion joints are provided in the roadway slab over the springings will show that movement does actually take place.

A better example even than this is the case of arch bridges in which no expansion joints are provided in the roadway construction over the springings, in which case a transverse fracture will invariably be found in the deck platform, unless, of course, the structure has been designed with such proportions and reserve of strength that the bridge as a whole does not work as an arch but, for instance, as two cantilevers joined at the crown.

The factors referred to above, producing actual shortening of a hingeless arch or a movement which is similar in effect so far as the deformation of the arch members is concerned, are given below :—

(1) Shrinkage of concrete during setting and hardening. The amount of arch shortening resultant from shrinkage, of course, differs according to the quality and mixture of the concrete employed, and also the manner in which it is placed in the work and allowed to mature. An average figure for the construction of an arch rib if placed in one operation is approximately 0·0004 of the length of the arch axis.

In view of the fact, however, that most ribs are placed in short lengths, the amount of arch shortening due to shrinkage after the ribs are continuous and connected to the abutments is reduced to a figure of from 0·0001 to 0·0002 of its length.

(2) The second factor producing arch shortening is the elastic compression of the arch rib, resultant from the thrust produced by the permanent and superimposed loading.

With the average compressive stress usually employed it is found that the shortening of an arch rib under this condition varies from 0·0001 to 0·00025 of its length, and the compressive stress induced by the deformation resultant from this elastic arch shortening is, it should be noted, quite distinct from and additional to the compression due to the thrust itself.

(3) The third and last factor is the settlement of the abutment supports when the gradually increasing thrust from the arch is brought upon them, and this, although not causing an actual shortening of the arch axis, produces moments and stresses in the same sense.

If the rise of an arch is small in comparison with the span, say $\frac{1}{10}$ or $\frac{1}{12}$, and the foundations are composed of a material which may be subject to appreciable compression, the stresses from this cause are of such a magnitude that they should not be ignored in the design of the structure. There is an insufficiency of reliable data to enable any definite figure to be given for this, but a settlement of the abutments of $\frac{1}{8}$ in. represents an equivalent shortening of an arch rib 100 ft. long of 0·0001.

In a hingeless or two-hinge arch there also should be added to the factors mentioned above the shortening due to a drop in temperature, which may well amount to the customary figure of 30° mentioned above. This variation of 30° from the mean temperature at which the bridge is assumed to be constructed produces a shortening of the arch axis of 0·0002 of its length.

The whole of the above effects tend to produce a particular form of deformation in the arch vault or ribs, and moreover this deformation is permanent throughout the life of the bridge, producing bending moments and stresses which are a maximum at the springings of the arch and also stresses at the crown amounting to about one-half of the former.

Taking the following figures as the actual or equivalent shortening of the arch members in a hingeless arch, the maximum compressive stress at their springings can be determined :—

Proportion of shrinkage producing arch shortening	0·0001
Compressive strain from permanent and superimposed loading producing arch shortening	0·0001
Assumed equivalent shortening of arch axis due to settlement of abutments . .	0·0001
Shortening of arch axis due to drop in temperature of 30° F.	0·0002
Total shortening of arch axis	0·0005 of its length.

Given this total figure it is possible to compute the equivalent horizontal force necessary to produce it, and having ascertained this, the bending moments and stresses produced at the springings and the crown of the arch can be determined.

The maximum compressive stress produced in the concrete of a hingeless arch for a shortening of 0·0005 may amount to anything between 450 and 700 lbs. per square inch. The exact figure, of course, depends on the inertia of the rib relative to its curvature. This maximum compressive stress is produced upon the concrete of a hingeless-arch bridge and is additional to the compression produced by the thrust due to permanent and superimposed loading and to those induced by bending moments caused by the various combinations of superimposed rolling loads passing across the structure.

Furthermore, the stresses produced by the arch shortening are a result of a particular deformation causing definite strains in the various parts of the arch, and consequently for any given case the stress is practically independent of the amount of longitudinal reinforcement that may be provided.

An inspection of the varying causes producing this stress will make it clear that it is in a large measure produced during construction. In other words, the dead weight of the structure itself, together with the proportion of shrinkage taking place whilst the bridge is being built, account for a large proportion of the above stresses.

This has been realised for some considerable time by Continental engineers, and devices are now employed which practically eliminate these effects.

The provision of mechanical hinges both at the springings and at the crown of an arch practically eliminate the above stresses, since these hinges permit any alteration in length of the arch to be easily accommodated by the unrestricted rise and fall of the crown.

There are, however, several practical disadvantages in connection with the employment of permanent hinges, principally on account of the necessity of a transversal expansion joint at the crown of the bridge and difficulty in architecturally treating a bridge of this type.

For some years past temporary hinges have been employed with the object of eliminating the stress produced by shrinkage, arch shortening, and settlement of the abutments, and in every case where such hinges have been employed, or other suitable provision made for the inevitable linear variations in the structure, no cracks or other defects have occurred, and the many bridges in which temporary hinges have been used are in a perfectly sound condition after years of use and provide additional evidence (if such is required) of the efficacy of such hinges.

At or immediately before the completion of the bridge, the concreting at the section where the temporary hinges are introduced is completed and the arch ribs act thereafter as hingeless or encastre members.

Even with the introduction of temporary hinges, it will be seen that a certain amount of arch shrinkage and shortening under load may take place when the bridge is completed and the arch members are in their final hingeless condition. The amount of such shortening, however, can be closely estimated when the bridge is being designed, and the equivalent horizontal thrust induced by this latter shortening can therefore be estimated.

This force, although infrequently of serious magnitude, is permanently present, and therefore causes moments in certain parts of the structure which limit the additional stresses permissible as a result of the vertical loading.

Where temporary hinges are employed in arch bridge design it is possible, by making these eccentric to the required extent in the cross-sectional sense, to impose moments throughout the arch which neutralise those produced by arch shortening when the arch is in its hingeless condition.

It is well known that temporary hinges consist essentially of a local reduction in the concrete cross-sectional area of the arch rib member. This reduced area should be made as small as possible in order that the required hinge action shall be realised. Moreover, it is necessary that the concrete hinge shall be reinforced in such a manner that it may, in addition to being highly stressed, be ductile in this condition.

SIMPLE EXAMPLES OF REINFORCED CONCRETE DESIGN.

By OSCAR FABER, O.B.E., D.Sc.

(*Continued from December*, 1923.)

EXAMPLE 5. RETAINING WALL

RETAINING walls are of many types, according to whether the vertical wall is on the side of the base slab nearer the earth to be retained (as in the present case) or on the other side (in which case the base slab is covered with the full height of earth.) The former kind requires a wider base, as it clearly is not so stable as when the base is heavily loaded with earth.

The pressure against a vertical face due to the weight of earth fill against it depends greatly on conditions, and chiefly on the nature of the soil. A rock face may exert no pressure at all, while a quicksand may exert a pressure as high as

$$p = 100h$$

where p is the pressure in pounds per square foot and
h is the depth below the free surface in feet.

It will be noticed that this assumes a pressure distribution varying uniformly from zero at the top to a maximum near the bottom. The author considers this a closer approximation to the truth than the newer theory of Meem.

Actual soils lie between these two limits, and the experience of the engineer is called in here to determine a correct figure for an actual case.

We will assume that in our case this pressure can reasonably be taken at

$$\underline{p = 30h}$$

which is a common figure for sound yellow clay and dry ballast.

If the free surface may be loaded (as by traffic, buildings, storage of goods, etc.) the front face will be subject to an additional pressure of

$p_1 = 30h_1$, where
h_1 is the height of earth,

which gives the same weight as the superload. In our case we will take the superload as 360 lbs. a sq. ft. (a common figure for a heavy floor or a street), whence

$$h_1 = \frac{360}{120} = 3 \text{ ft.}$$

[120 being the weight of the earth in lbs./cu. ft.]

and $p_1 = 30 \times 3 = 90$ lbs./sq ft.

This additional pressure p_1 is a constant pressure right down the back of the wall.

CALCULATIONS OF STRENGTH.

The front wall may be considered as a cantilever fixed near the bottom, and loaded by these horizontal pressures.

The worst point is generally at the point *A*, at the top of the haunch, hence moments about this point should first be calculated as follows :—

[See *Fig.* 16 for pressure diagrams, etc.]

Due to Super Load.—

Pressure due to super load =

$$30 \times 3 = 90 \text{ lbs. a sq. ft.}$$

Total pressure down to A $= 16 \times 90 = 1{,}440$ lbs.

Moment about A $= 1{,}440 \times 96$ in. $= 138{,}000$ in.-lbs.

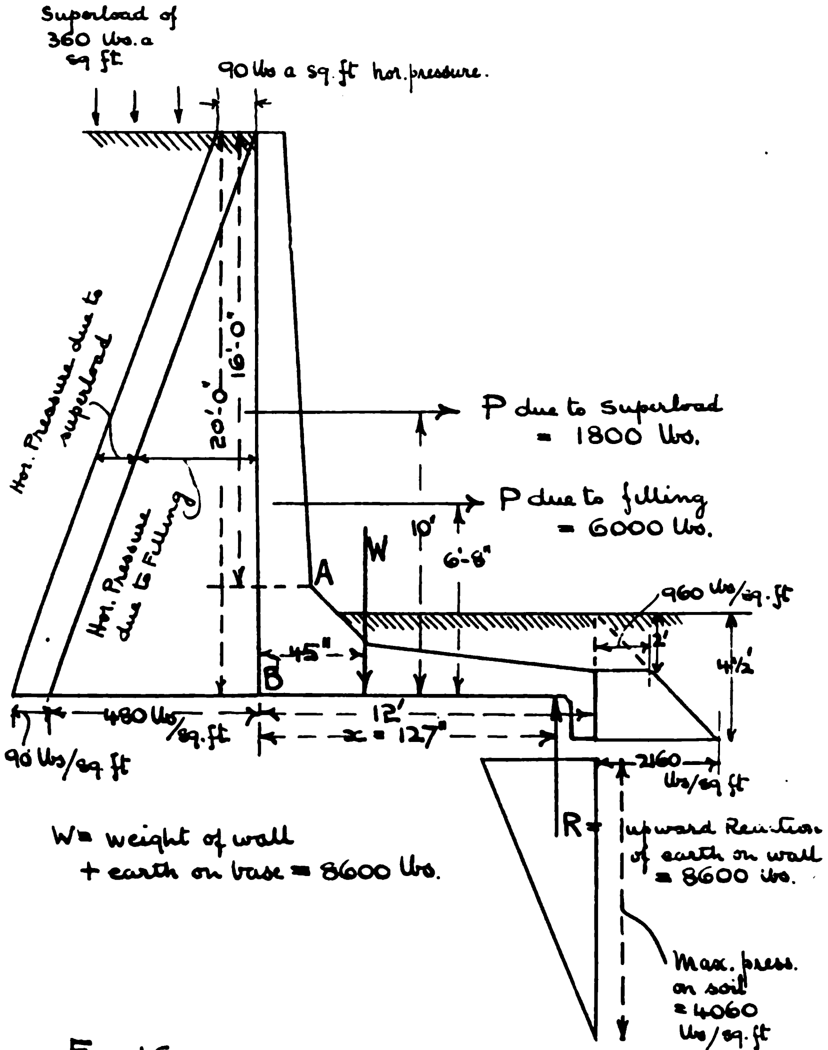
Superload of 360 lbs. a sq. ft
90 lbs a sq. ft hor. pressure.
Hor. Pressure due to superload
Hor. Pressure due to Filling
20'-0"
16'-0"
P due to superload = 1800 lbs.
P due to filling = 6000 lbs.
10'
6'-8"
W
A
B
45"
960 lbs/sq. ft
2'
4½'
480 lbs/sq. ft
90 lbs/sq. ft
12'
x = 127"
2160 lbs/sq ft
R = upward Reaction of earth on wall = 8600 lbs.
Max. press. on soil = 4060 lbs/sq. ft
W = weight of wall + earth on base = 8600 lbs.

Fig. 16

Diagram of forces and pressures governing stability

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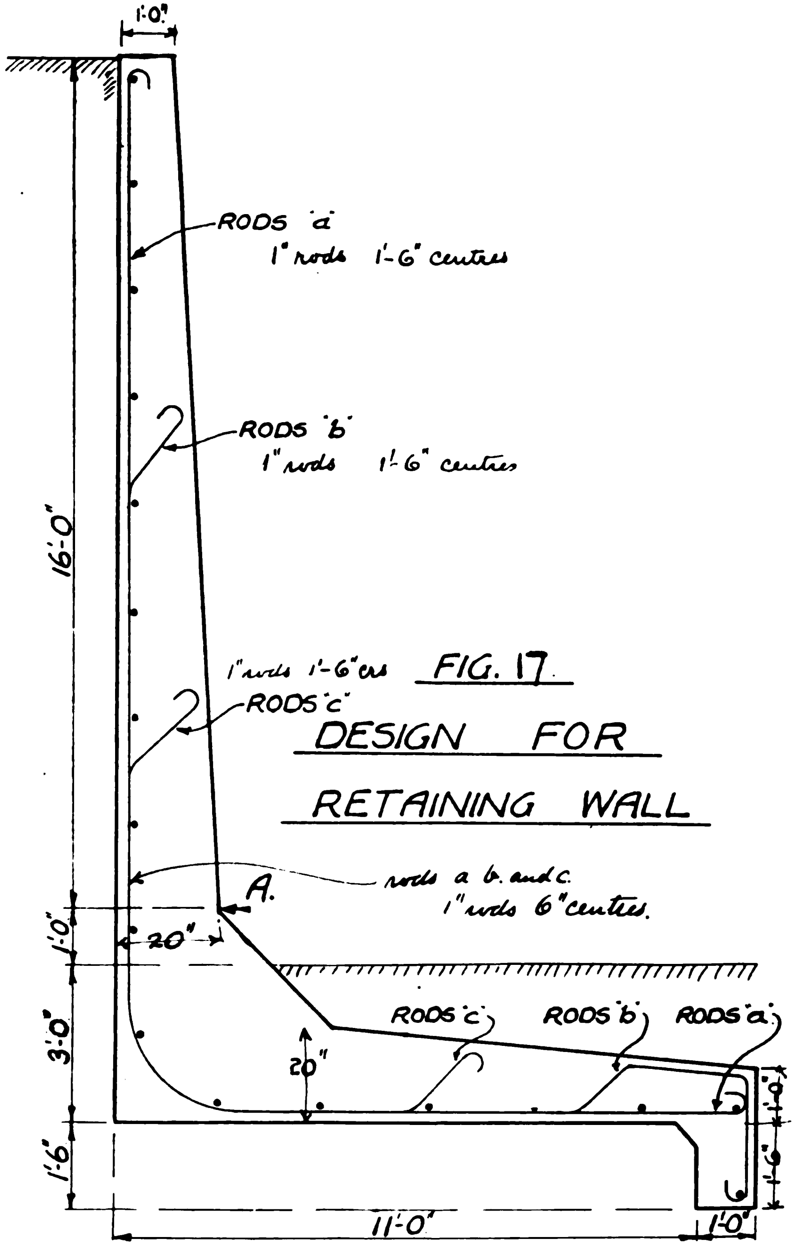


FIG. 17.

DESIGN FOR RETAINING WALL

Due to Filling behind Wall.—

Pressure varies from 0 at the top to

$$30 \times 16 = 480 \text{ lbs. a sq. ft.}$$

at the bottom.

Hence average pressure is 240 lbs. a sq. ft.

Total pressure above A is

$$16 \text{ ft.} \times 240 = 3{,}840 \text{ lbs.}$$

This pressure has a triangular distribution, and therefore its resultant lies at a distance of

$$\frac{h}{3} = \frac{16 \times 12}{3} = 64 \text{ in.}$$

from A.

Hence moment about A

$$= 3{,}840 \times 64 \text{ in.} = 246{,}000 \text{ in.-lb.}$$

Hence total moment about A

$$\begin{aligned} &= 138{,}000 + 246{,}000 \\ &= 384{,}000 \text{ in.-lbs.} \end{aligned}$$

Taking the resistance moment at

$$R = 95\ bd^2$$

and remembering that $b = 12$ in. [since we are considering a 12 in. width of wall] we have

$$\begin{aligned} d &= \sqrt{\frac{384{,}000}{95 \times 12}} \\ &= 18 \cdot 4 \text{ in.} \end{aligned}$$

Whence $h = 20$ in.

allowing a small cover of concrete.

The formula $R = 95\ bd^2$ is based on a percentage of 0·675 of steel.

Whence the area of steel per foot run of wall required is

$$\begin{aligned} A &= \frac{0 \cdot 675}{100} \times 12 \times 18 \cdot 4 \\ &= 1 \cdot 5 \text{ in.}^2 \end{aligned}$$

Hence 1 in. diameter rods at 6 in. centres give what is required.

It is not necessary for all these to run to the end, as the moment decreases rapidly as the top of the wall is approached, as may be seen by a trial further up.

The best arrangement in the present case is to divide the rods into three kinds, (*a*), (*b*), and (*c*), bent as shown in the figure and placed alternately. This will give one-third of the rods going to the top, two-thirds some two-thirds of the way up, and all the rods for about the lower third.

SHEAR.

The shear across *A* is clearly 1,440 + 3,840 = 5,280 lbs. The shear resistance is

$$60 \times 18 \cdot 4 \times 12 = 13{,}200 \text{ lbs.}$$

so that no question as to this arises.

This is practically always the case with walls of this type.

OTHER SECTIONS.

The student would do well to repeat the moment calculations for other sections.

STABILITY.

As has been mentioned, strength is one thing, stability another. The latter depends on whether the resultant of all the forces (weight and pressure) lies sufficiently inside the base to give reasonable pressures on the soil.

In the present case, the weight may be calculated approximately as follows :—

Wt. of front wall per ft. run

$$= 20 \text{ ft.} \times 1\tfrac{1}{2} \text{ ft.} \times 150 = 4{,}500 \text{ lbs.}$$

Wt. of base slab and earth on it

$$= 10\tfrac{1}{2} \text{ ft.} \times 3 \text{ ft.} \times 130 = 4{,}170 \text{ lbs.}$$

The centres of gravity of these lie respectively about 9 in. and 81 in. from the point B. Hence the centre of gravity of the whole lies about 45 in. from B.

For stability we must now consider the horizontal pressures on the whole front face of the wall 20 ft. deep.

Due to Superload—

Pressure due to superload

$$= 90 \text{ lbs. a sq. ft. as before.}$$

Total pressure on front wall

$$= 90 \times 20 = 1{,}800 \text{ lbs.}$$

moment about B $= 1{,}800 \times 120 \text{ in.} = 216{,}000 \text{ in.-lbs.}$

Due to Filling—

Pressure varies from 0 at the top to $30 \times 20 = 600$ at the bottom. Hence the average pressure is 300.

Total pressure above B is $20 \times 300 = 6{,}000$ lbs.

moment about B

$$= \frac{6{,}000 \times 240 \text{ in.}}{3}$$

$$= 480{,}000 \text{ in.-lbs.}$$

The total overturning moment about the point B is therefore as follows :—

Due to weight of wall 8,600 lbs. × 45 in. =	387,000 in.-lbs.
,, ,, superload	216,000 ,,
,, ,, filling	480,000 ,,
Total	1,083,000 ,,

This has to be resisted by the contrary resisting moment due to the reaction on the soil.

This reaction has a vertical component equal to the weight of the wall

$$W = 8{,}600 \text{ lbs.}$$

Hence the horizontal distance of this reaction from the point B must clearly be

$$x = \frac{M}{W}$$

$$= \frac{1{,}083{,}000}{8{,}600}$$

$$= 127 \text{ in.}$$

This point is therefore $144 - 127 = 17$ in. from the right-hand side of the base.

Assuming a triangular distribution of the upward pressure of the soil on the base, whose resultant has to come at this point, it follows that the length of base subject to such upward pressure is

$$3 \times 17 = 51 \text{ in.}$$

Hence the average pressure on the soil over this distance is

$$p = \frac{W}{A} = \frac{8{,}600 \text{ lbs.}}{\frac{51}{12} \text{ ft.}^2} = 2{,}030 \text{ lbs/ft.}^2$$

the maximum pressure being twice the average in triangular distribution, the ***maximum*** pressure is

$$p = 4{,}060 \text{ lbs./ft.}^2$$

or just under 2 tons a sq. ft., which is safe on most soils.

The above calculations will be clearer by reference to the diagram in *Fig.* 16. Notice that the base is $\frac{6}{10}$ the height of the wall and just sufficient for stability. Where the superload is relatively greater—in proportion to the earth pressure—this may require increasing; where it is negligible, the ratio may come down to $\frac{1}{2}$.

Where the vertical wall is at the other side of the horizontal base, so that the base is earth-covered to the full height, the ratio may be as low as $\frac{4}{15}$.

Sliding—

Walls sometimes fail by sliding and not by overturning, and care must be taken as regards this. The horizontal pressure is 1,440 + 3,840.

$$P = 5{,}280 \text{ lbs.}$$

The vertical weight of wall is

$$W = 8{,}600 \text{ lbs.}$$

If sliding is to be prevented by friction on the base, the coefficient of friction would require to be

$$\phi = \frac{5280}{8600} = 0{\cdot}62.$$

This is very high, and could hardly be relied on except on a rocky base with a rough surface. With ordinary earth foundations of dry clay, ballast, etc., a figure of 0·25 is generally safe.

[Note, however, that a *wet* clay surface may give much less and must be guarded against.]

In that case, the horizontal force resisted by friction is

$$\cdot 25 \times 8{,}600 = 2{,}150 \text{ lbs.}$$

leaving 5,280 − 2,150 = 3,130 lbs. To resist this, a heel beam has been provided in the design.

The safe horizontal pressure of such a surface against the earth (before the earth pushes away) depends, of course, on the earth, but may (under average conditions of sound yellow clay or ballast) be taken as

$$p = 480\,h$$

where h is the depth in feet below the free surface and p the pressure in lbs. per sq. ft.

In our case, h at the top of the heel beam is

$$h = 2$$
$$\text{whence } p = 960 \text{ lbs. a sq. ft.}$$

At the bottom of the heel beam

$$h = 4\tfrac{1}{2}$$
$$p = 2{,}160 \text{ lbs. a sq. ft.}$$

Therefore the mean safe pressure is

$$p = \frac{960 + 2160}{2} = \frac{3120}{2}$$
$$= 1{,}560 \text{ lbs. a sq. ft.}$$

Hence the safe resistance is

$$1{,}560 \times 2\tfrac{1}{2} = 4{,}400 \text{ lbs.}$$

[$2\frac{1}{2}$ being the sq. ft. of surface of the heel beam against the resisting earth.]

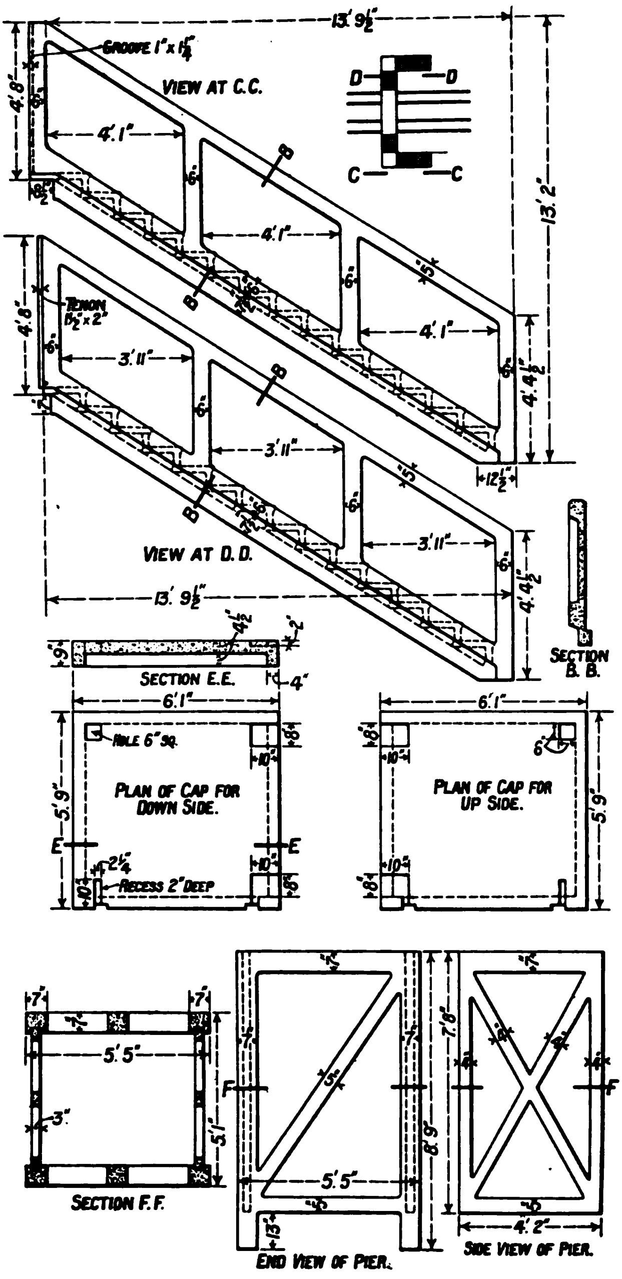
As this exceeds our pressure of 3,130 lbs. to be provided against, we are clearly on the safe side.

PRACTICAL POINTS.

See that the back of the wall is drained by filling loose rubble immediately behind and *adequate* weep holes near the bottom for egress of water.

See that the foundation is cleaned *dry* and loose mud removed before concreting the footings, to prevent sliding.

(*To be continued.*)



Details of Side Flights, Piers, and Caps.

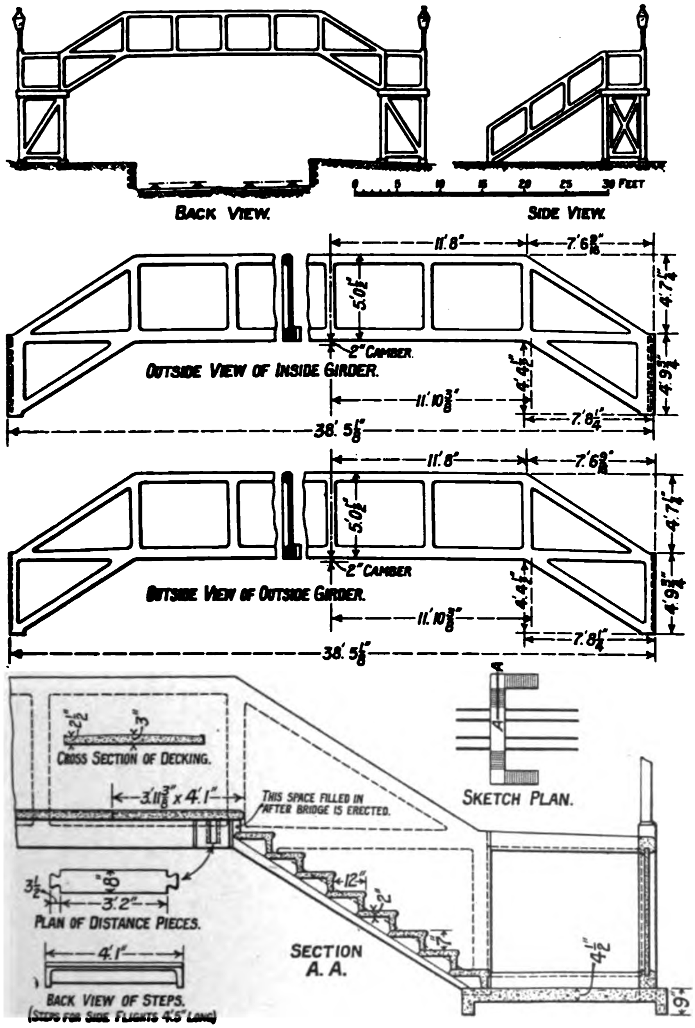
PRE-CAST REINFORCED CONCRETE FOOTBRIDGE. (*See* p. 19.)

A PRE-CAST REINFORCED CONCRETE FOOTBRIDGE.

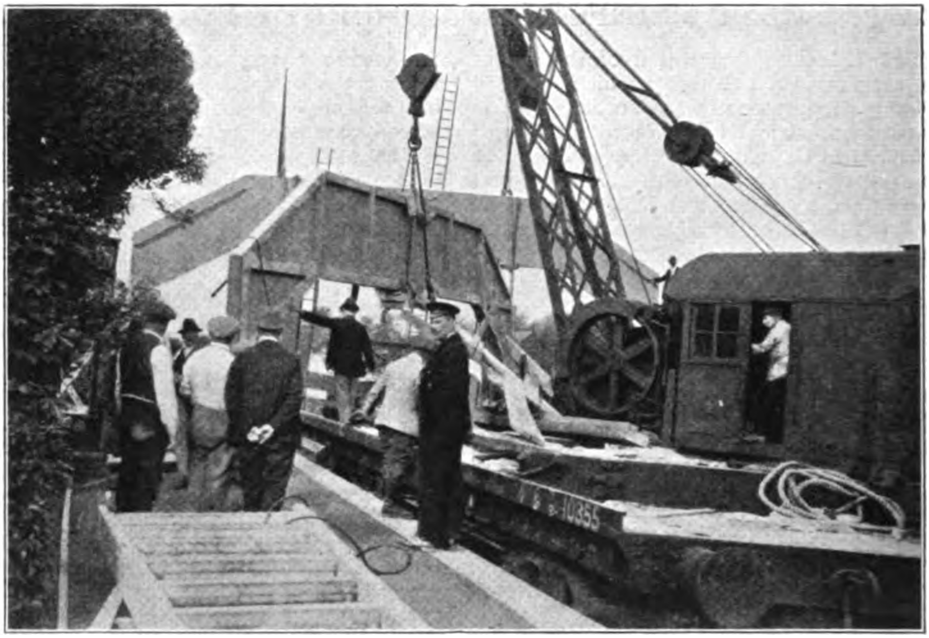
The following description of the reconstruction of a footbridge which recently took place at one of the stations on the writer's District of the Southern Railway will, it is thought, be of general interest to those concerned with constructional work in concrete, although the utilisation of the railway tracks was an essential feature of the work.

The condition of the original footbridge, a timber structure erected some thirty-five years ago, rendered complete renewal necessary, and it was decided to make use of the existing foundations for a reinforced concrete structure.

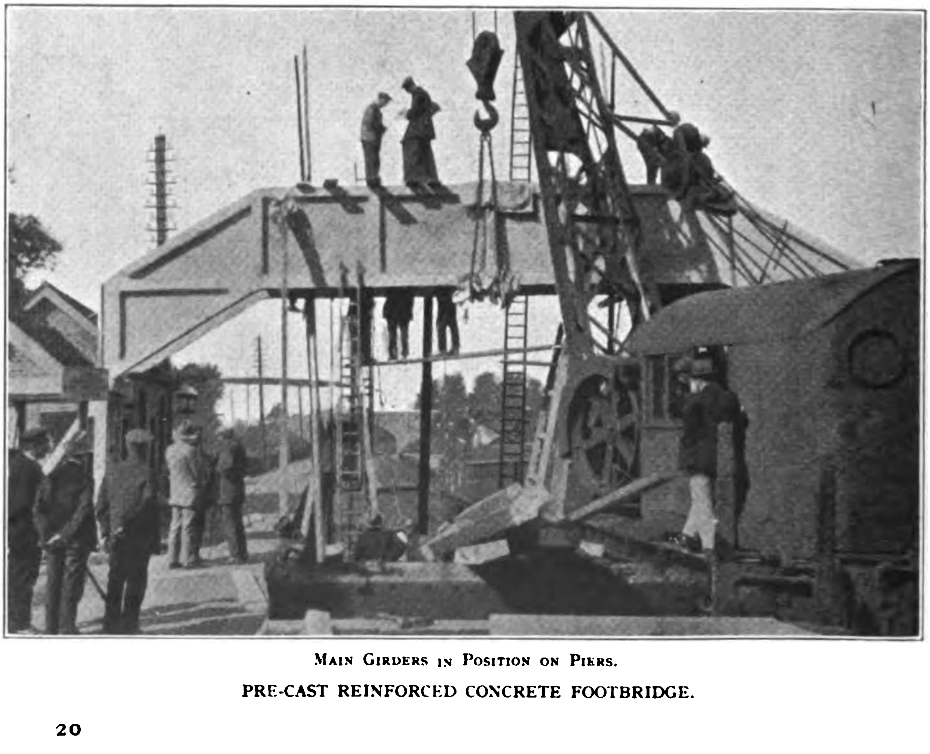
The writer suggested that the whole bridge should be pre-cast at the Company's Concrete Depôt at Exeter, delivered on the site in sections, and erected with the aid of a loco. steam crane. A suitable design for this purpose was accordingly worked out, and submitted



Outline Drawing of Bridge and Details of Main Girders.

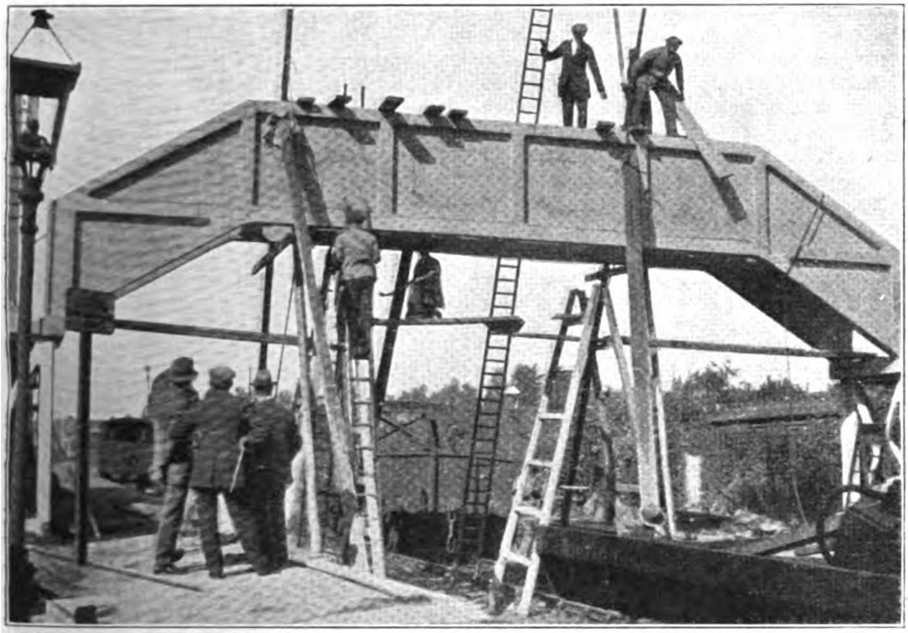


Locomotive Crane Hoisting Second Main Girder into Position.

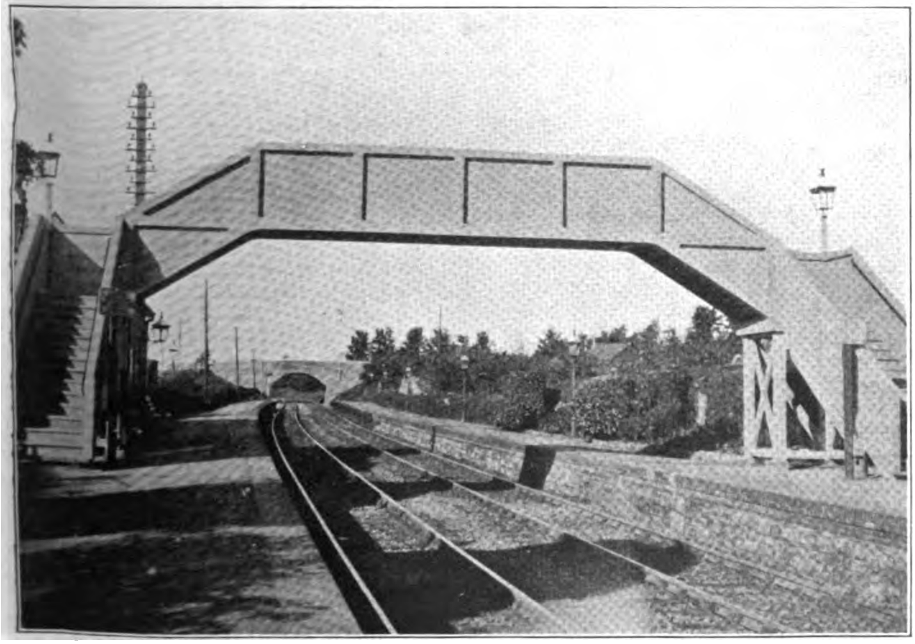


Main Girders in Position on Piers.

PRE-CAST REINFORCED CONCRETE FOOTBRIDGE.



Cross-Ties between Main Girders being Dropped into Place previous to Insertion of Steps and Floor Slabs.



General View of Completed Bridge.

PRE-CAST REINFORCED CONCRETE FOOTBRIDGE. (*See p.* 19.)

to Headquarters for approval. The feature of the design was the casting of the main girders separately and on their sides instead of in an upright position, and also the separate casting of the sides and tops of the two braced piers, the floor slabbing, and the staircase treads.

The braced sides of the piers were designed to fit at the bottom into the cast-iron sockets provided for the old timber footbridge, and at the top to be firmly held together by the landing slabs, which are made in the form of caps. To hold the main girders together four reinforced concrete cross-ties were arranged to be dropped into projecting sockets provided on the inside of the girders just below floor level.

The necessary moulds, which were very simple, were put in hand as soon as the design had been approved, the various parts cast and allowed to season for two months before arrangements were made for erection. The two main girders were delivered to the site loaded upright on a 40-ton 45-ft. bogie rail wagon, and the remaining parts loaded flat on two other wagons.

The demolition of the old bridge was commenced at midnight on a Saturday and completed by 6 a.m. on the Sunday. The erection of the new bridge was then commenced with the aid of the steam crane, and by 11.30 a.m. the two trestles and both main girders were in position. The track was then cleared for a passing train, and on resuming the erection of the staircase girders was taken in hand, followed by the insertion of the steps and floor slabs, the work being completed and the bridge opened for passengers' use by 7 p.m. All joints not grouted up on the Sunday were grouted the following day.

The accompanying illustrations and extracts from the detail drawings clearly show the type of construction and method of erection. Round steel rods varying in diameter from $\frac{5}{16}$ in. to $\frac{3}{4}$ in. were used for the reinforcement, but as this is quite normal in its arrangement details have not been reproduced except in the case of the main girders, which had to be so reinforced that they could be lifted and uprighted, after being cast on their sides, without temporary bracing. This was managed by extending the bottom member of the girder in a straight line across the diamond-shape end panels and keeping the reinforcement of this member uniform from end to end. The bed of the girder mould was also subdivided so that the beds of the first and fifth intermediate vertical members were separate and could be utilised for lifting the girder in the first instance, it being just strong enough to support its own weight when lying on its side and so supported.

No bolts or tie rods are anywhere used to hold the various parts of the bridge together, all parts being designed to be mutually supporting when once fitted together; further, no reinforcement is anywhere exposed for the purpose of joint making.

As regards cost, it may be said that after adding 20 per cent. of the cost of the moulds, which will be used for the casting of other similar bridge sections, the total cost was not as much as that of the reconstruction of a similar bridge in steel which took place at another station about the same time, and it must be remembered that the steel bridge will require painting from time to time, while the concrete bridge will not.

Although the resultant structure is not monolithic, it is felt that, owing to the favourable Depôt conditions under which the various sections were made, the quality of the concrete is superior to that which would have been produced by casting *in situ*. Moreover, the fact that the structure can be and was erected in less than twenty-four hours, and that no falsework is wanted, is an immense advantage from a railway point of view, and at once puts reinforced concrete work on an equality with steel.

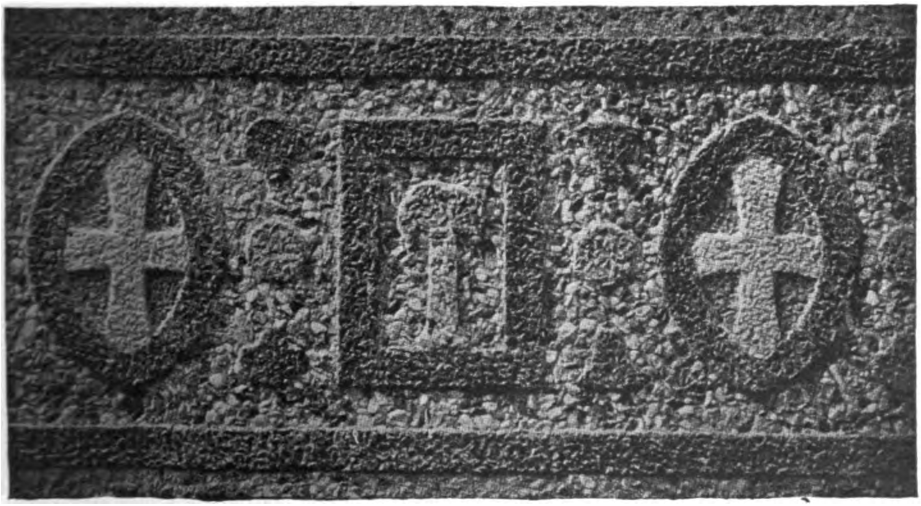
In conclusion, the writer has to thank the Chief Engineer of the Southern Railway, Mr. A. W. Szlumper, C.B.E., M.Inst.C.E., for kindly granting permission for the publication of the above description.

[We are indebted for our illustrations to "The Railway Gazette and Railway News."]

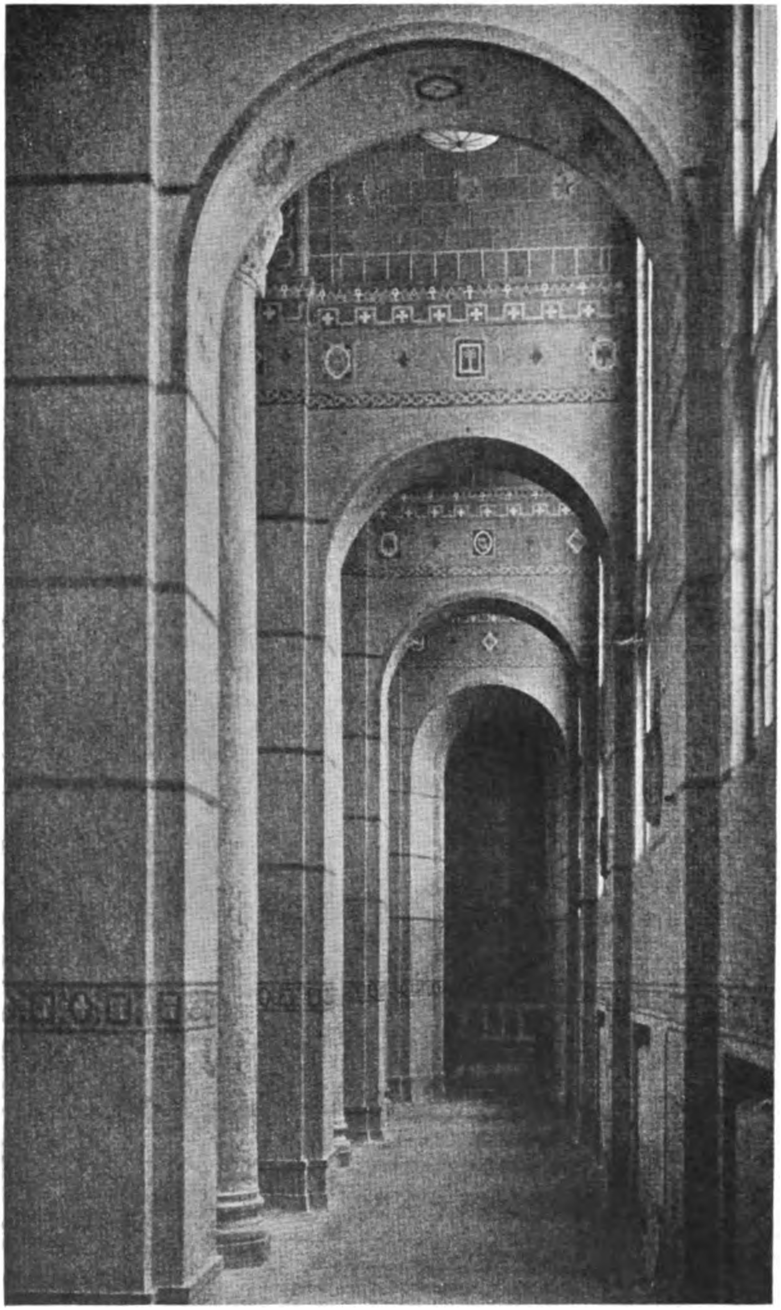
CONCRETE IN CHURCH ARCHITECTURE.

THE growing appreciation of concrete as a material for executing the best architectural conceptions finds frequent expression nowadays, and is admirably demonstrated in the churches illustrated in this issue, one in the United States and one in France. In the latter case concrete was used solely on account of its cheapness compared with other materials, and whatever opinions may be held on the design of the structure the confidence of those who selected concrete as the most economical structural material is amply justified by the spacious building which has been obtained for a small outlay.

Taking the early Romanesque style of the cities of Northern Italy for example, the remarkable Church of the Sacred Heart, Washington (which we illustrate in our Frontispiece and on p. 24), takes a conspicuous place amongst monumental structures of the city, and it is especially interesting as illustrating the use of concrete in buildings of architectural design. Messrs. Murphy and Elmsted, the architects, are to be congratulated on their work, which is dignified both in its design and treatment and in the grace of its general proportions. The church is cruciform, with an unusually wide nave, completing with the apse a construction logically and liturgically characteristic of the Roman Catholic Church. Concrete is the material used in the building, and we are justified in saying that the results achieved demonstrate the adaptability of concrete for the purpose, and the attractive results to be obtained through the material. Its adaptability extends almost over the entire field of construction, including ornament as well. The long corridors formed by the side aisles of the nave, logically expressing the material used, reach through it a quite remarkable beauty—a beauty quite of their own, while they suggest in so doing a new and distinctive architecture growing out of the characteristics of the material. This working through the material of concrete itself, instead of using forms which have been the growth



DETAIL OF ORNAMENTAL BAND IN CONCRETE AT THE CHURCH OF THE SACRED HEART, WASHINGTON.
(*See also Frontispiece.*)



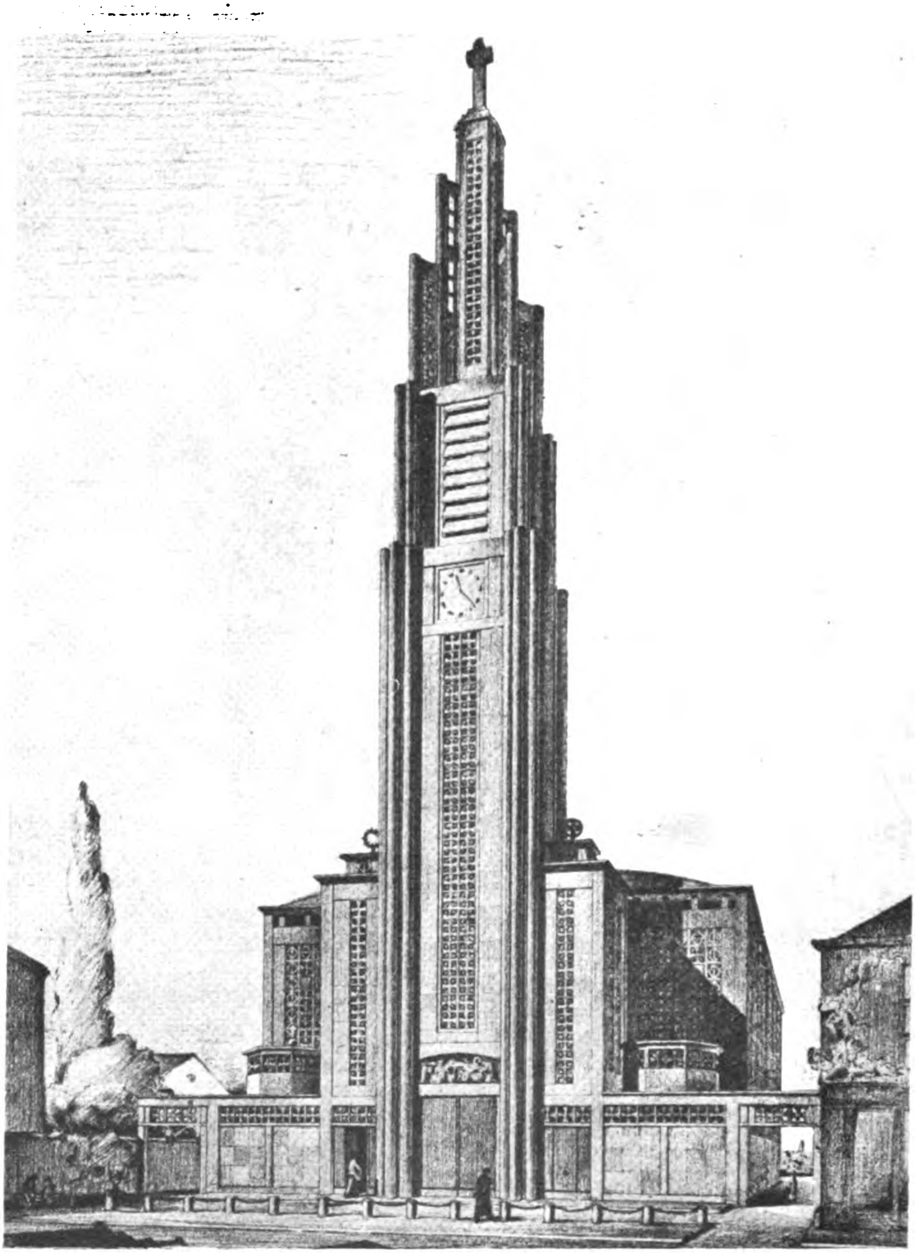
[Messrs. Murphy & Elmsted, Architects.

ONE OF THE SIDE AISLES AT THE CHURCH OF THE SACRED HEART, WASHINGTON.

through other materials, such as stone or brick, and without the conventions of style, foretells a new spring-time in building. On the other hand, the architects show an adherence to tradition which helps to establish an *ensemble* at once impressive and original. Original in the right sense, not as failing to acknowledge what is due to the past and the traditions of such a building, but expressing these through a sympathy which withholds nothing from the legitimate claims of their own personal feeling in the matter. The architect is thus not less but more himself in resting his own resources on this background, and arrives therefore at a self-expression unbiassed by any conscious straining after originality, so often a hindrance to the best work.

In the capitals of the columns use is made of extremely ancient forms from the earliest period of the Christian era, and this feature of early work is seen also in the character of the choir loft. The front of the choir loft to the nave is surmounted by a parapet or protecting wall perforated as a means of ornamental effect, and maybe to lighten it as well. The results remind one of early Italian work, and have something of the same purity of grace and feeling. In the ornament seen through the arches on each side of the western doors, below the choir loft, and above the delicate archways on either side forming a screen in front, one can see the admirable effect derivable through the glow of colour showing through these apertures.

The detail of an ornamental band (illustrated on p. 23) at the five-foot level, showing the different textures of the aggregate, is interesting, and suggests the many possibilities lying in it for ornament; at the same time the finer textures are better in effect than too coarse a mixture which is not so agreeable in surface for ornament of such a character, and perhaps it is felt more in this instance, owing to the character of the design. It has also to be remembered, however, that as yet the resources of concrete for ornament are in an early stage of development. There is always the danger of the scope of the craftsman being too much impeded at the very outset, unless the co-operation between architect and craftsman is very close and enlightened. The architect may be a paper designer; the craftsman designs more through his material, with that always in view, and the distance of the architect from direct contact with material often leaves a gulf unbridged between the two. Moreover an architect thinks in terms of architecture, and when it comes to decorating his building his mind may not readily absorb the scope, stretching beyond himself, of the craftsman's help, and he should leave a little more to him. There is neither first nor last in art, and if we are again to have vital and spontaneous ornament it will grow out of, and through, its background of masonry, as the rose blossoms out of stalk and leaf. It is not a case of relative importance, but of difference of nature; and the difficulty with the architect, and it constantly impedes the prospects of the best decoration, is that he would—in the familiar phrase—tie it too much to his own apron strings; imposing on it too much of an abstract nature, thinking still in the terms of building structure when we are concerned with wholly other conditions. The rose is not like the leaf, though a logical growth out of it. As a result, and it is seen in this building, the decoration is all too timid, producing a spotty and superficial effect, and we should often be better without it. We see how in Italy and Greece this corporate intelligence, exercised with fuller freedom, sustained a greater equality of achievement and enlarged the scope of the

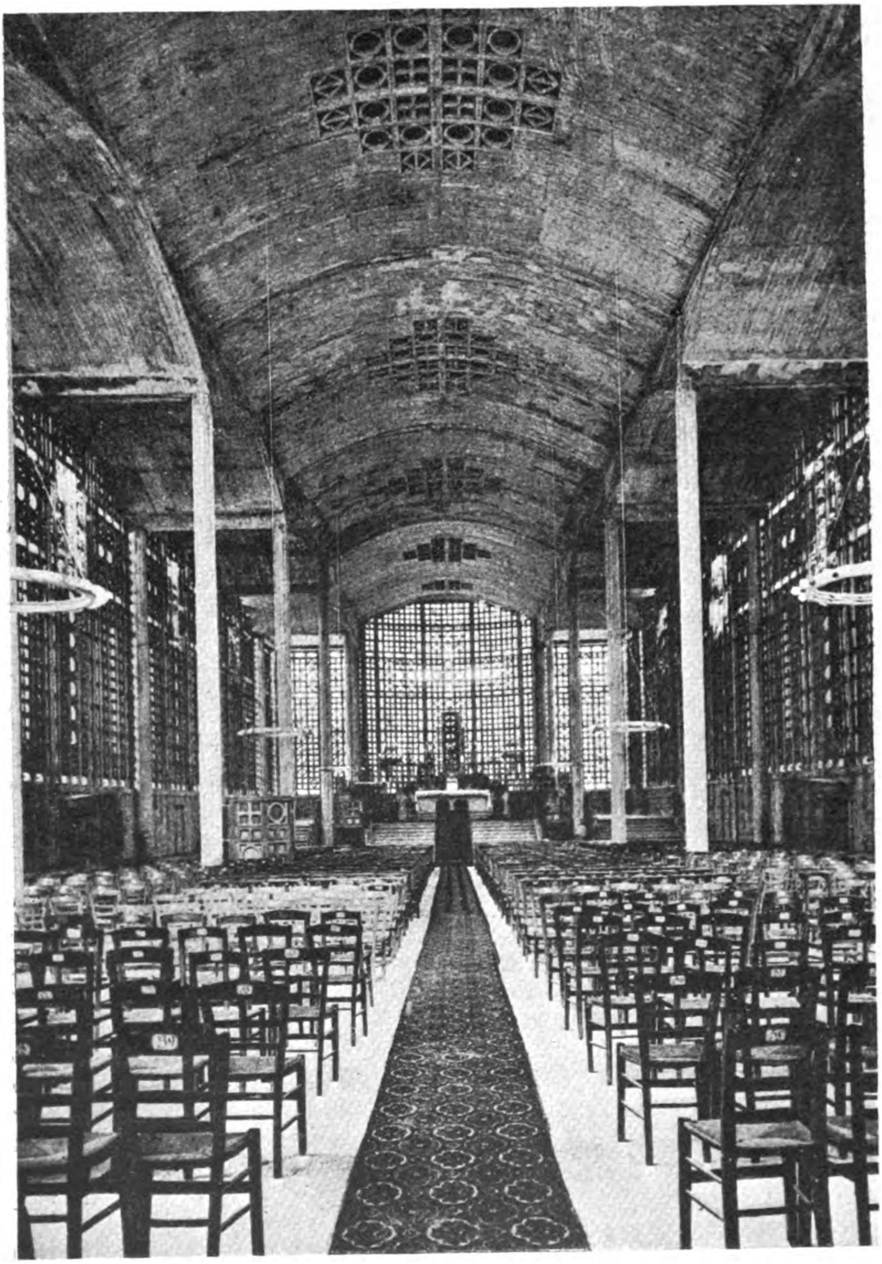


CONCRETE CHURCH AT RAINCY, FRANCE. (*See p.* 31.)

adventure, surprising us in the richness of the personality and variety expanding through the building. But if this has to be said to keep before us the enlarging possibilities for architecture as this co-operation between the parts is better sustained, we desire to give at the same time full credit to the taste and enterprise of the architects.

Symbolic decoration has no doubt its important place, but symbolism needs constantly to be renewed, to continue the life in it, and it is not enough in itself. A writer in the *American Architect* describing these decorations says: "It is believed that the symbolic decoration gives the church a much greater interest than the usual method of ornamentation without this historic or symbolic meaning." Well: That depends. If it is nothing more than the outworn symbols of mediævalism it does not seem to us that there is much interest at all. Some of us would like to exorcise the Tudor rose and the fleur-de-lys, so exhausted are we by their endless repetition. These dull conventions and repetitions cannot wholly supply the place of fresh and living conceptions, nor should it be forgotten that the great periods of art have always shown immense interest in including the ideals and interests of their own time. A greater self-respect should lead us to incorporate more of our own and not to live on the past as well as enjoying it. One's belief in the future of concrete as a building material for all purposes is confirmed in looking at the results obtained in the Church of the Sacred Heart; its scope and application are so wide that there is no necessity for any special pleading such as we have seen recently in the case of other materials. But in our appreciation of concrete we must not fall into the mistake of granting to a material more than belongs to it. We all know the sort of people who ask us to admire the new oak reredos—with special emphasis on the "oak"—a reredos which may very well be bad both in design and craftsmanship. In thus placing the emphasis our values are wrong, because man is greater than his materials, and a material is often bad or good according to the skill with which it is worked. Even the most unaccommodating material has been found to yield a good result where there have been found the intelligence and invention to cope with it, and with a plastic material such as concrete the scope is unlimited. Neither is the cost of a material any criterion of its worth for a particular purpose. We recall a church built entirely of marble some years ago, and at an immense cost, than which we have perhaps never had the honour of seeing a worse. We need to keep our common sense uppermost, claiming more for the intelligence of man than "sticks and stones." If there are those who deprecate concrete as a material for architectural purposes, we can only then blame their experience, and the way it has been used—not the material itself, which is seen in the instance of this Church of the Sacred Heart to compare on equal terms with any other material whatever, and to include in addition its own particular characteristics; new forms arising through its constructive necessities revealing new possibilities for architecture.

A report of an interview with Mr. John J. Earley, under whose direction the decoration was carried out, is given on page 29.



CONCRETE CHURCH AT RAINCY, FRANCE: GENERAL VIEW OF THE INTERIOR. (*See p.* 31.)

CHURCH OF THE SACRED HEART, WASHINGTON.

By the courtesy of our contemporary, *The American Architect*, we are able to give the following report of an interview with Mr. John J. Earley, who was responsible for the interior decoration, in concrete, of the Church of the Sacred Heart, Washington, illustrated in this issue :—

" The interior of the Church of the Sacred Heart, in Washington, showed such a high order of craftsmanship, such intimate and successful co-operation between the architect and the architectural sculptor, that we looked up John J. Earley, who either on his own part or that of a group of well trained craftsmen of which he is the head, executed the ornamental features of the interior. It is to men like Earley and Samuel Yellin to whom we must look in this country for the highest development of our craftsmanship. Elbert Hubbard truly wrote,—' Blessed is the man who has found his work.' Few of the master craftsmen in this country prove that they have found theirs.

" Is architecture as a fine art passing ? Has the work which is held up for our emulation, and on which the traditions of our profession rest, become impossible ? Will the artist-architect and his specialist assistant, the architectural sculptor, pass in our age because the cost of reproducing design in permanent media is greater than the economics of the time will support ? These were the questions which were asked.

" ' The problem as a whole has two phases,' said Earley, ' an academic and an economic one. In designing this church time and effort were not considered. Every detail was the most important thing on the job. All available information was sought, personal experiences were reviewed and discussed, symbols were authenticated ; every effort was made that the work might be a textbook on the subject. But notwithstanding this, the point of view maintained was always that of the artist and not that of the archæologist.

" ' The execution was characterised by the same energy and the same interest as the designing. The men in my studio worked with an enthusiasm which was remarkable. I often think that there was revived in all concerned the same mediæval spirit which in years gone by had built the cathedrals of Europe for the sheer joy of building.

" ' The sheer joy of building ! ' Was it possible that such a sentiment could exist among craftsmen to-day ? We thought that fine spirit was lost centuries ago. The words came from Earley with the sharp staccato of a rapid-fire gun. No more questions from us, the man fired by enthusiasm for his topic hurried on. He said :—

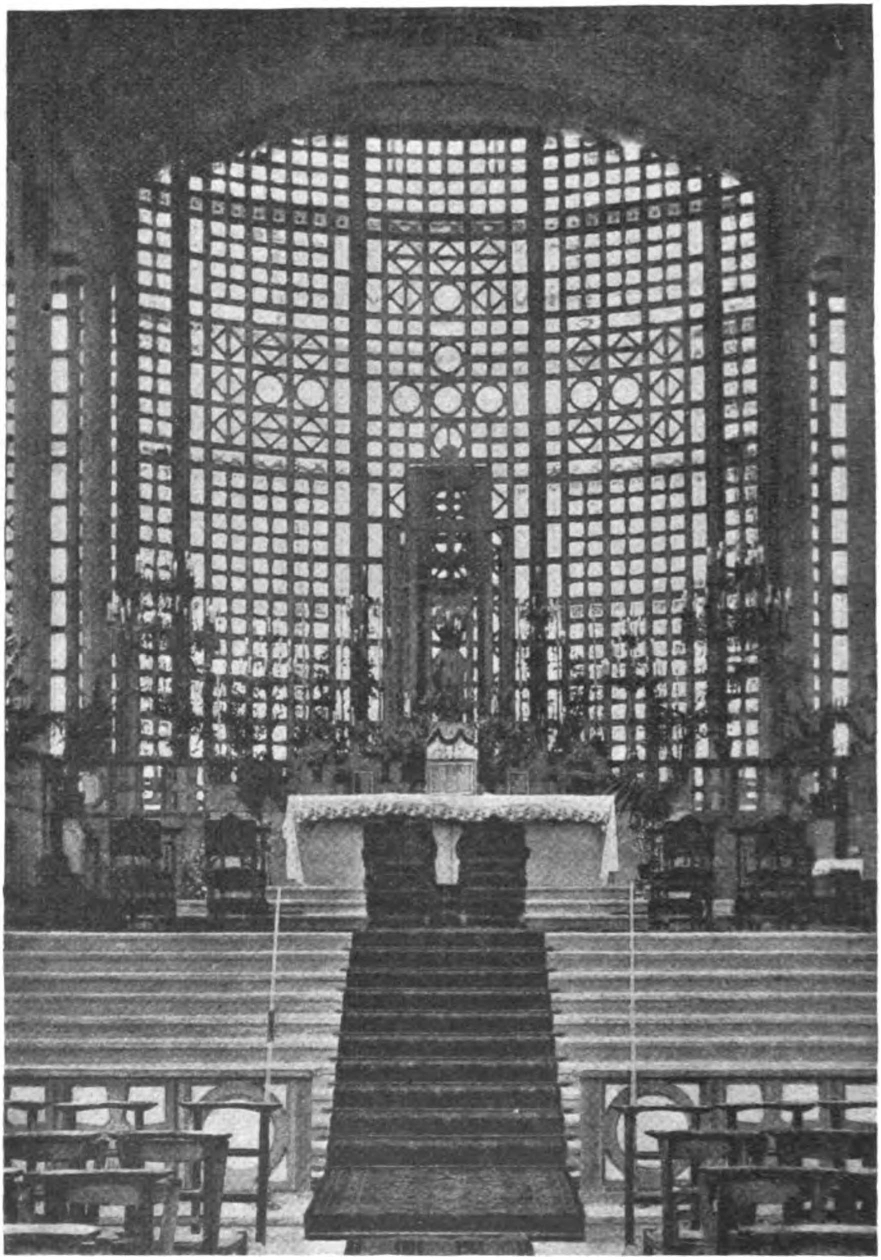
" ' I have executed architectural design in all of the standard media, and of all, whether stone, metal, plaster, glass, or concrete, I prefer to work in concrete. It is more responsive than any other material ; it is more flexible. My preference for this medium is shared with equal enthusiasm by every architect for whom I have used it.

" ' The Church of the Sacred Heart therefore stands as a testimonial of what an able architect can do with concrete and of what concrete can do for architects. If concrete is a thoroughly acceptable architectural material, as architects who have used it testify, this church means that architecture is once more in balance with the economics of the times, and that the architect is free to exercise his genius to design buildings with an appearance proper to their value and the circumstances of their use.

" ' Architectural sculptors,' said Earley, " have for years struggled against the suppression of their art by increasing costs. Not the cost of design nor of study, but the cost of executing design in permanent materials.

" ' They have employed every means devisable to overcome the difficulty. They have tried the economy of better management, the simplification of design ; they have slighted finish, cut profits to the point of loss, and finally lowered standards. All of which have proved to be only proverbial straws at which a drowning man will grasp.

" ' Some years ago it become clear to me that the economy which would be basic, which would again permit the freedom of design such as existed before industry took the profusion of skilled workmen from the arts, would rest upon new principles ; it would be cut from



CONCRETE CHURCH AT RAINCY, FRANCE: SHOWING THE CONCRETE TRACERY OF WHICH PRACTICALLY THE WHOLE OF THE WALLING IS FORMED. (*See p.* 31.)

new cloth and to a new pattern. However, I made no more progress toward a solution of the problem than did my confrères until fortuitously my attention was attracted to concrete as a possible medium of artistic expression. A commission to carry out certain work in this material and its generous response to my unskilled efforts encouraged me to improve my knowledge of concrete in the hope that it would prove to be an economic and facile material.

" 'The culmination of these efforts is the work on the interior of the Church of the Sacred Heart.'

" All of which is food for thought."

CONCRETE CHURCH AT RAINCY.

The construction of the new church at Raincy (Seine-et-Oise), illustrated in this issue, has involved several new principles of design, and, therefore, is of considerable interest. It has been built as a war memorial, and it was regarded as essential that the building should be as beautiful and impressive as possible notwithstanding the fact that it had to be built very cheaply, no marble, stucco or other applied ornament being procurable with the sum available.

The architects, MM. Perrch, have overcome this difficulty in a remarkable manner by the use of moulded concrete, the effect being excellent.

The edifice, which covers an area of 13,300 sq. ft., consists of three principal parts : (1) the porch, surmounted by a tower 143 ft. high ; (2) the interior proper, measuring 120 ft. by 70 ft., and including the chief and two subsidiary naves ; and (3) the choir and apse, both built on a platform 5 ft. above ground level.

The central tower is flanked on each side by a subsidiary tower, containing respectively the baptistry and the chapel dedicated to the dead soldiers. The central tower consists of four sets of columns with panels between, the whole supporting the superstructure which carries the cross. This method of construction constitutes the chief novelty in the design, and it imparts a peculiar elegance to the structure. Just above the doorway space has been left for a large plaque in low relief, depicting the descent from the Cross.

The decoration consists of simple moulding forming a formal trellis-work, which adds greatly to the light and airy appearance of the structure.

The columns in the interior are few in number, and of very small diameter, being 35 ft. high and only 5 in. wide. The roof over the central nave is arched longitudinally, but that over each of the subsidiary naves consists of a series of transverse arches.

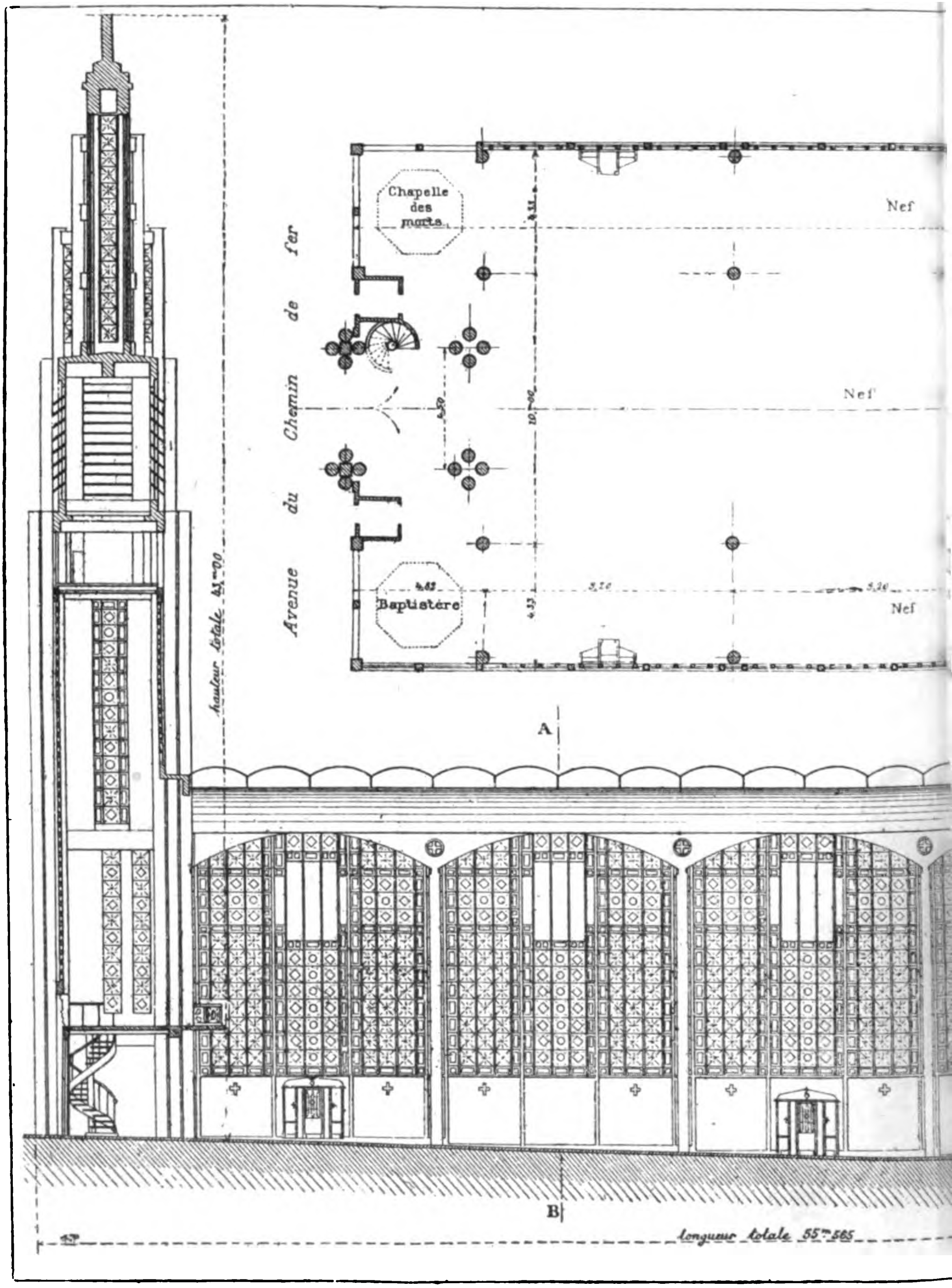
The side walls consist almost wholly of open-work moulding of simple geometrical form, dispensing with more formal windows and admitting an unusually large amount of light into the interior.

The heating is effected by passing the air through a steam heater placed below the choir stalls.

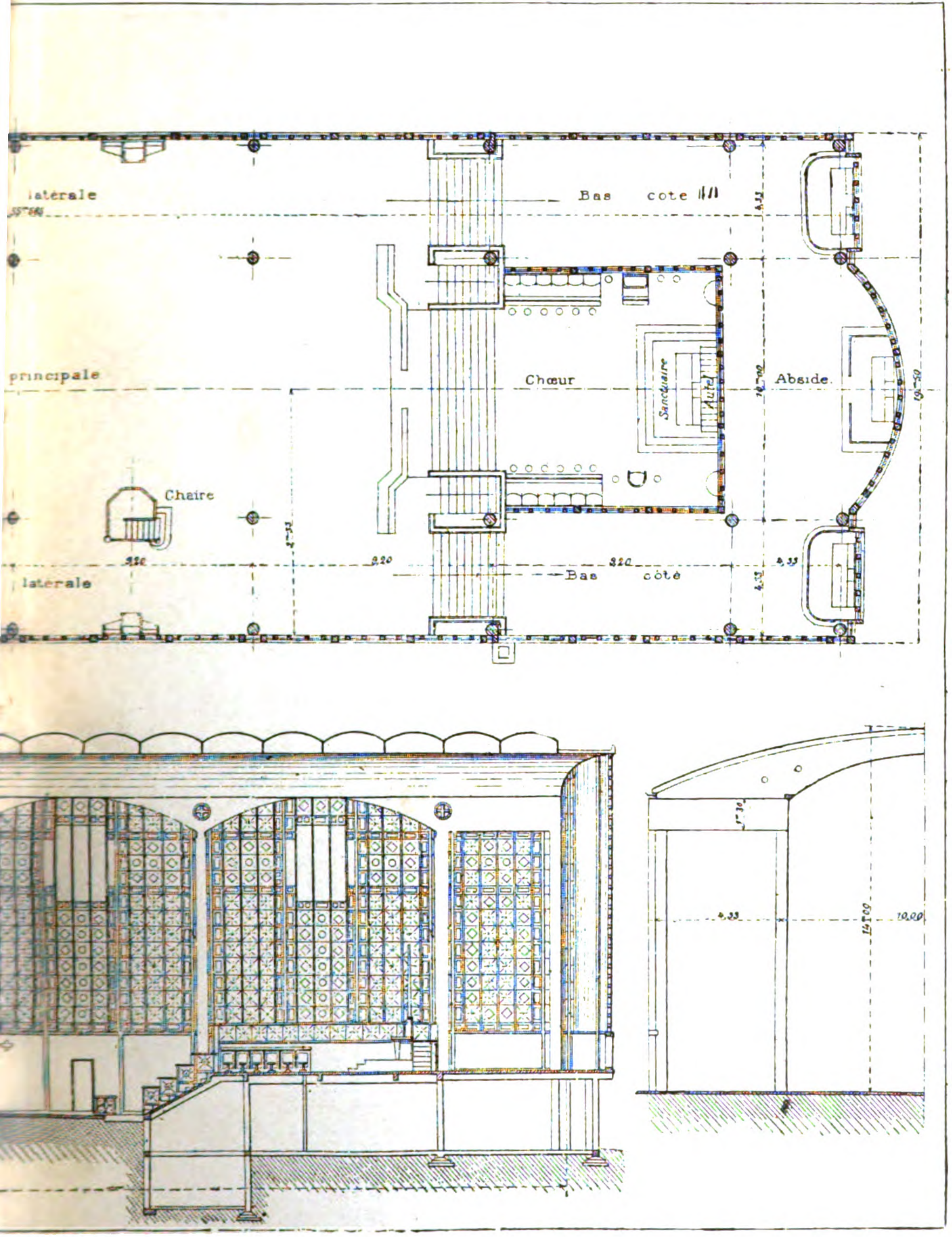
Special care has been taken in calculating the strengths of the various parts of the structure, to ensure its stability as a whole. The tower, in particular, is calculated to resist any wind pressure to which it is likely to be exposed, even in the strongest gale.

The building was erected in a little over a year at a cost of 600,000 francs, or a little more than £12,000 ; had it been built of stone, it would have cost at least three times as much and would have required more than two years to erect.

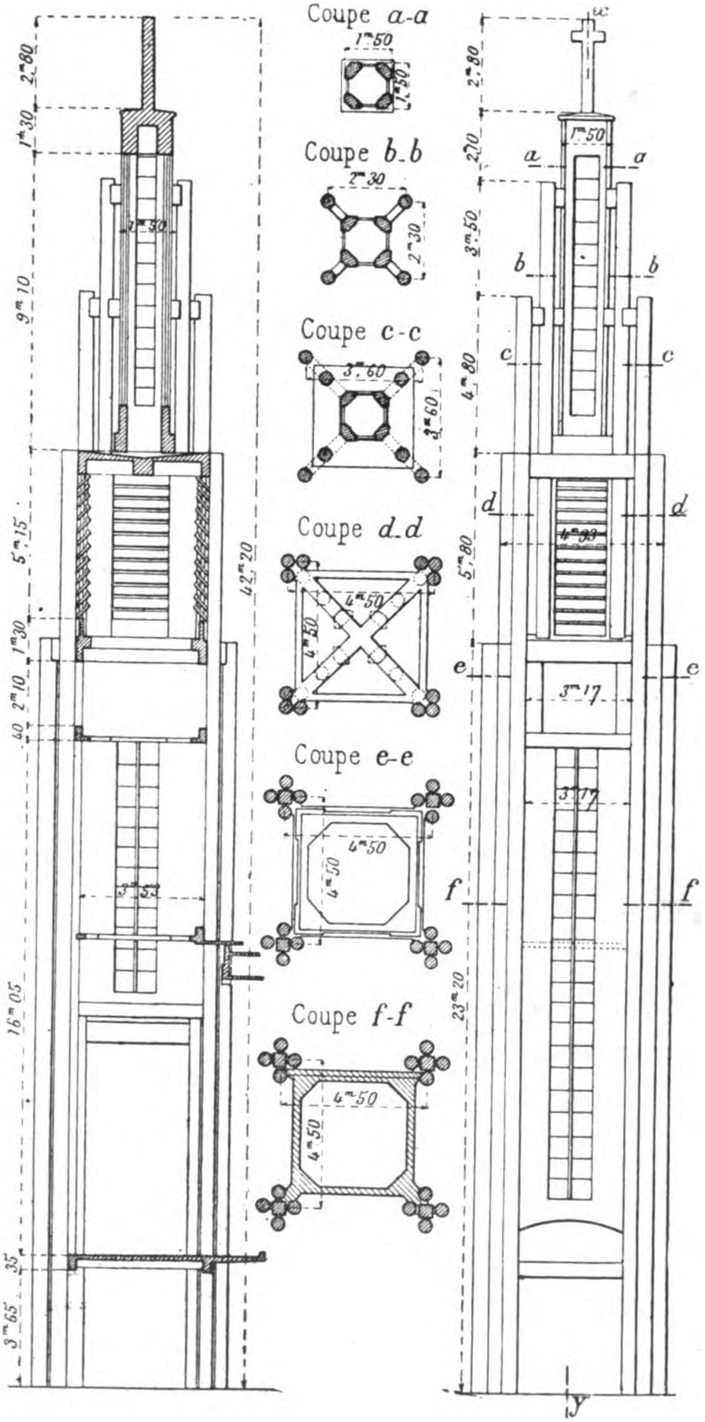
Our illustrations of this church are reproduced by courtesy of *Le Genie Civil*.



CONCRETE CHURCH AT RAINCY, FRANCE



PLAN AND LONGITUDINAL SECTION. (*See p.* 31.)



CONCRETE CHURCH AT RAINCY, FRANCE: VERTICAL AND HORIZONTAL SECTIONS OF TOWER (*See p.* 31.)

REINFORCED CONCRETE IN A PRINTING WORKS AT PELAW.

In our October issue we published illustrations and a description of a large granary building with silos which was constructed by the Co-operative Wholesale Society at Avonmouth. On pp. 36-37 we now illustrate another large building, also practically entirely in reinforced concrete, which has been constructed by the same Society, who have been one of the pioneers in this country in employing reinforced concrete extensively. The illustrations which we reproduce are of a large printing works at Pelaw, near Newcastle-on-Tyne, the general plans for which were prepared by Mr. W. G. Townsend Gray, Architect of the Co-operative Wholesale Society at Newcastle, and the working drawings for the reinforced concrete work were executed by Messrs. Edmond Coignet, Ltd., of 125 Gower Street, W.C.1.

Reinforced concrete, of course, lends itself particularly well to this class of building on account of the uniform nature of the work, which is composed of several floors and a flat roof. All the bays in the floors and roof are standardized so as to be of equal dimensions ; this, of course, is very economical on account of the fact that the centering can be used several times without alteration.

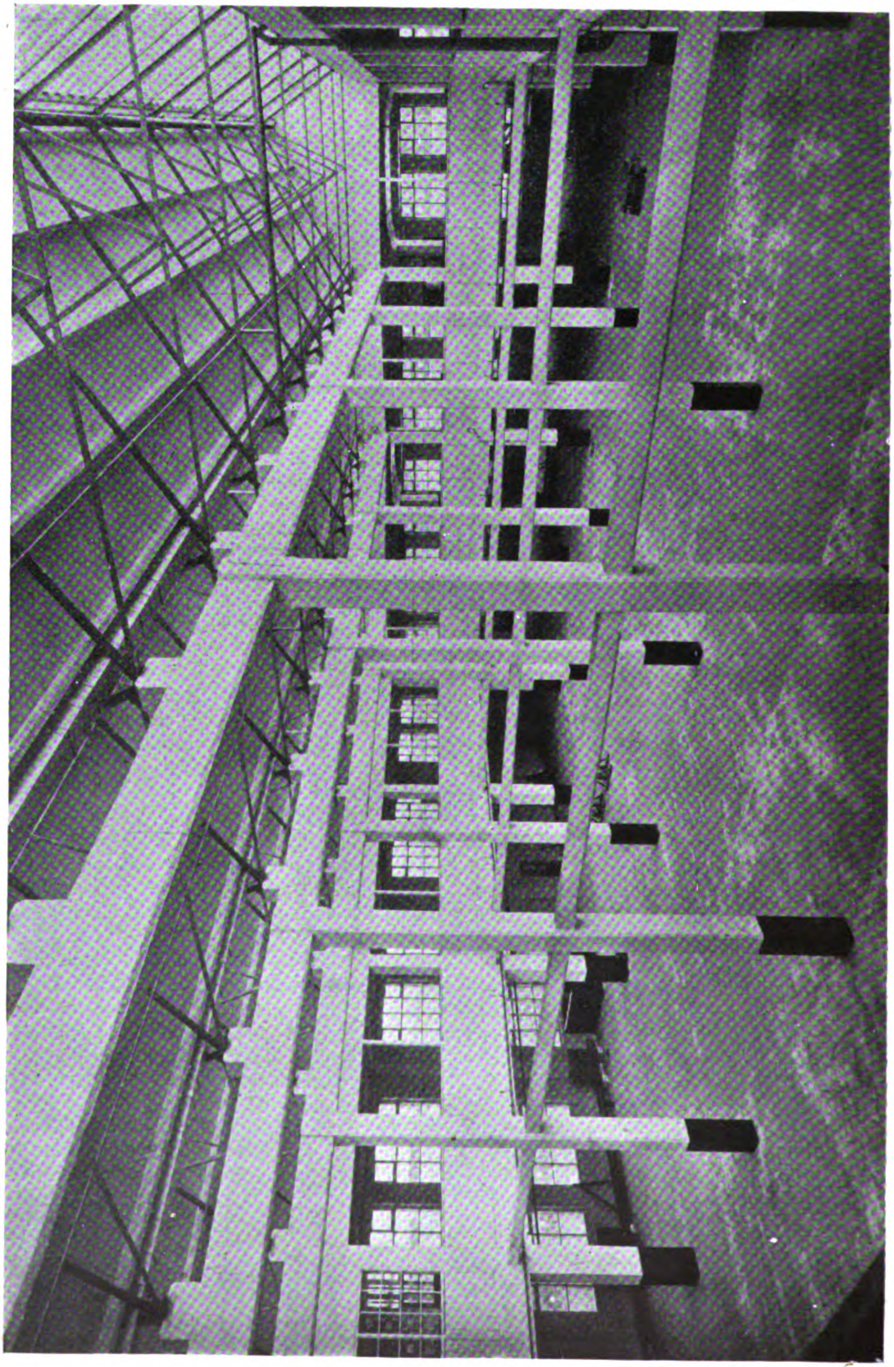
The building contains a basement in ordinary concrete, and a ground floor and first floor in reinforced concrete, calculated to carry a superficial load of 3 cwts. per sq. ft. There is a flat roof covered with asphalte, calculated for ½ cwt. per sq. ft. The staircases are also in reinforced concrete, so that the whole structure is fire-resisting. For architectural effect, brickwork was used for the construction of the walls.

The building has been made very light by the introduction of several glass lantern lights to the roof, and also by the numerous large windows, as shown in the photographs. The ground floor is covered with a 1-in. thickness of cement, granite finished, and the reinforced concrete floors are covered by rough boarding finished with ⅞-in. tongued and grooved maple boarding on wood fillets 3 in. deep laid on the top of the slabs. Coke breeze concrete has been placed between the fillets to keep them in position. A lavatory block adjoining the building is also constructed in reinforced concrete. As indicated by the views of the interior, the whole of the underside of the floors and the pillars has been distempered cream colour, with the exception of the bases of the pillars, which are painted brown. This has the effect of producing a clean and uniformly lighted interior.

As the basement of the building in certain parts is below the ground level, a retaining wall was constructed in this portion.

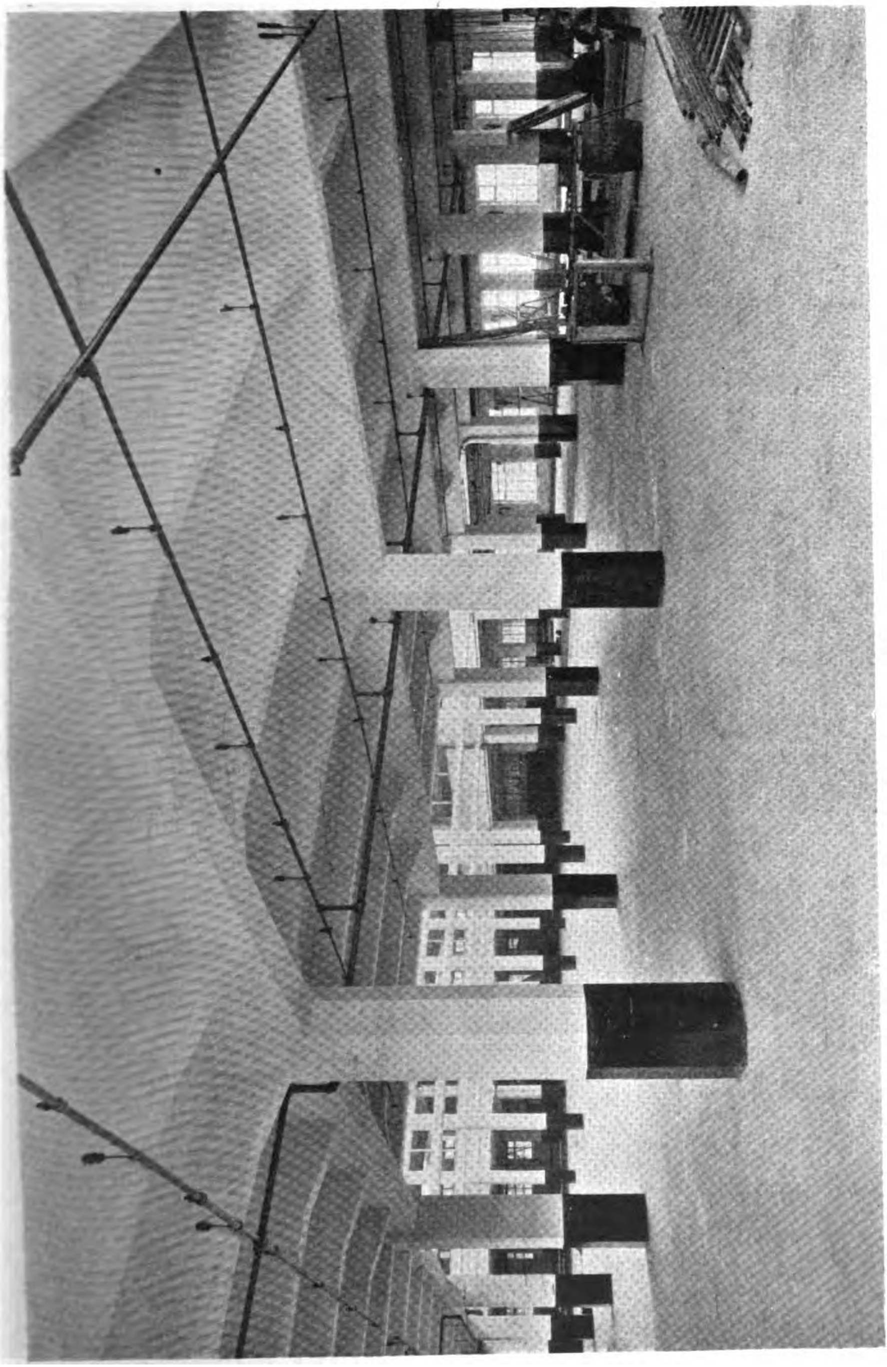
The general dimensions of the building are approximately 202 ft. long by 145 ft. wide. The height between the basement and ground floors is 12 ft., and the height between the ground floor and the first floor 14 ft. The height of the second floor, however, is 13 ft. All the floor slabs are 5 in. thick. Although most of the pillars are of rectangular section, the intermediate pillars supporting the floors are octagonal in shape. A certain portion of the ground and first floors in the centre of the building, measuring about 95 ft. long by 70 ft. wide, has been left open without any floors, and a large glass lantern roof covers this portion of the building. As the pillars carrying this lantern roof are a considerable height, it has been necessary to brace them against wind pressure, in the manner shown in the illustration.

The reinforcement was composed entirely of round bars of mild steel in accordance with the Coignet system of construction. The mixture of concrete was 1 : 2 : 4. The entire work was executed by the Co-operative Wholesale Society's Building Department.

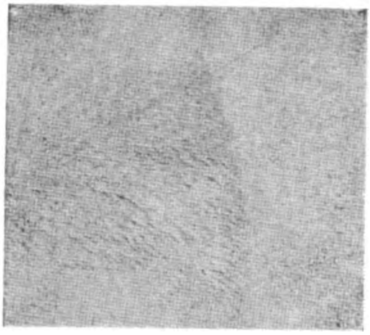


PRINTING WORKS AT PELAW. *(See p. 35).*

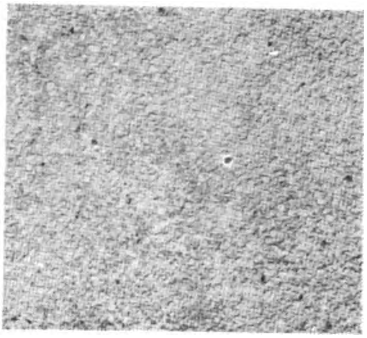
CONCRETE IN A PRINTING WORKS AT PELAW.



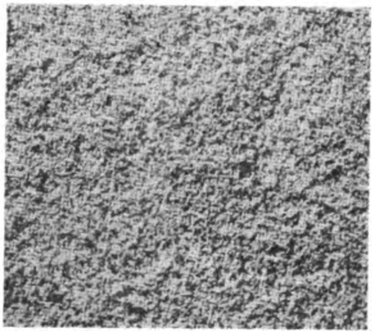
PRINTING WORKS AT PELAW. (*See* p. 35.)



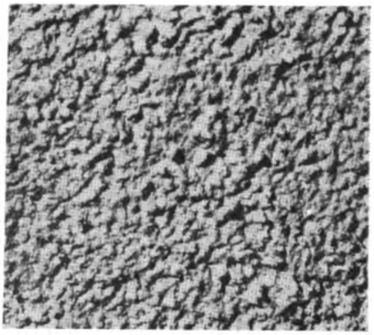
SAND FLOATED.



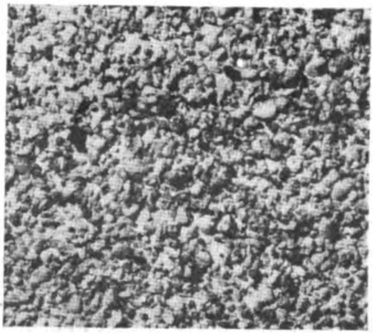
EXPOSED AGGREGATE.



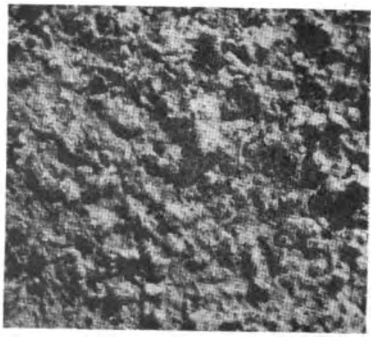
SAND SPRAYED.



STIPPLED.



PEBBLE DASH.



SPATTER DASH OR ROUGH-CAST.

CEMENT-STUCCO FINISHES. (*See p.* 39.)

CEMENT-STUCCO FINISHES.

In this issue we give a number of illustrations of different cement exterior treatments which have been developed in America, where these methods of obtaining attractive surface finishes are being extensively used. The variety of textures which may be obtained in cement stucco is practically only limited by the skill of the workers, and no expensive tools or extra materials are required. In all the examples illustrated the effect has been obtained by the manipulation of the trowel or ordinary stippling brush.

The effects of the most common methods of treatment are shown on p. 38, and the following brief notes on the way in which they are obtained may be of interest, although much depends on the skill of the operative.

Stippled.—The finishing coat should be trowelled smooth with a metal trowel with as little rubbing as possible, and then lightly patted with a brush to give an even stippled surface.

Sand Floated.—The finishing coat, after being brought to a smooth, even surface, should be rubbed with a circular motion of a wood float with the addition of a little sand slightly to roughen the surface. This floating should be done when the mortar has partly hardened.

Sand Sprayed.—After the finishing coat has been brought to an even surface, it should be sprayed by means of a wide, long fibre brush, dipped into a creamy mixture of equal parts of cement and sand, mixed fresh at least every 30 minutes, and kept well stirred. This coating should be thrown forcibly against the surface to be finished while the finishing coat is still moist and before it has attained its early hardening.

Rough-Cast or Spatter Dash.—After the finishing coat has been brought to a smooth, even surface with a wooden float, and before it has finally hardened, it should be uniformly coated with a mixture of 1 part of cement to 3 parts of fine aggregate thrown forcibly against it to produce a rough surface of uniform texture when viewed from a distance of 20 ft. Special care should be taken to prevent the rapid drying out of this finish by thorough wetting down at intervals after the stucco has hardened sufficiently to prevent injury.

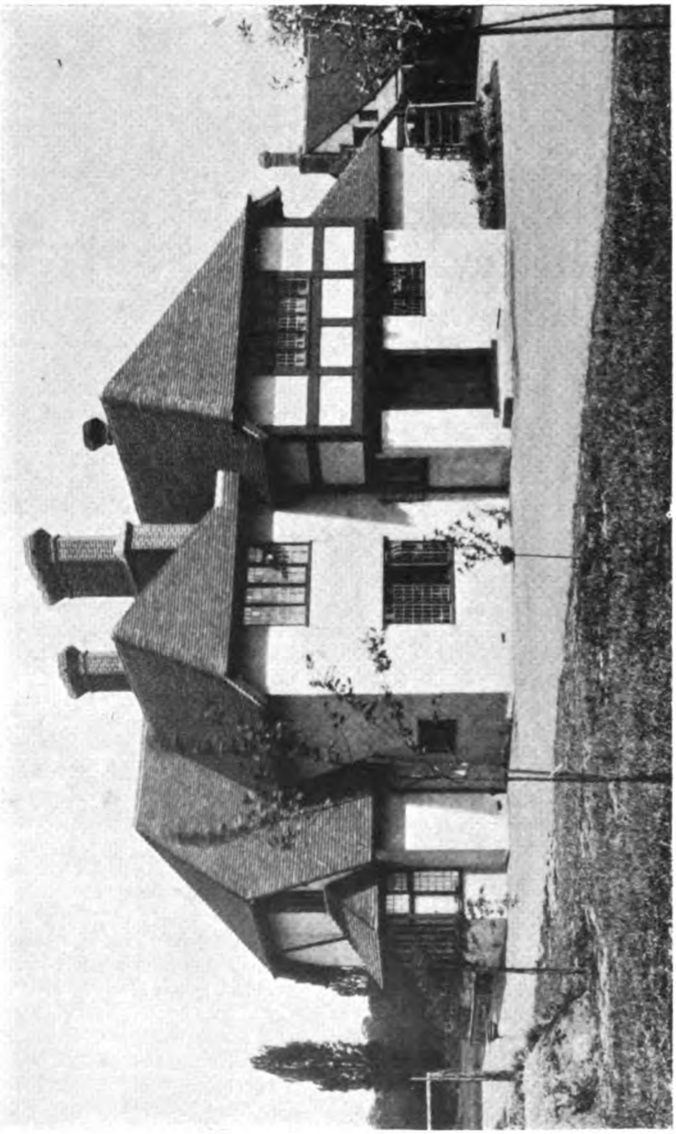
Pebble Dash.—After the finishing coat has been brought to a smooth even surface, and before it has begun to harden, clean round pebbles, or other material as selected, not smaller than ¼ in. or larger than ¾ in. and previously wetted, should be thrown forcibly against the wall so as to be embedded in the fresh mortar. The pebbles should be distributed over the mortar with a clean wood float, but no rubbing of the surface should be done after the pebbles are embedded.

Exposed Aggregate.—The finishing coat should be composed of an approved, selected coarse sand, crushed marble or granite, or other special material, and within 24 hours after being applied and trowelled to an even surface, it should be scrubbed with a stiff brush and water. In case the stucco is too hard, a solution of one part hydrochloric acid in four parts of water by volume can be used in place of water. After the aggregate particles have been uniformly exposed by scrubbing, particular care should be taken to remove all traces of the acid by thorough spraying with water from a hose.

The other textures shown in the illustrations have been produced by various methods of manipulation of the plastic material, mostly by the intelligent use of the trowel. In general, the rougher the texture of a stucco the more attractive the appearance, as very smooth stucco is apt to give the effect of a coat of paint at a short distance. A rough texture stucco, with consequent lights and shadows, gives a wall surface of life and interest, particularly if the wall is viewed from a distance.

Stucco can be coloured in two ways: by the use of mineral pigments or by the use of coloured sands, and if any colouring is desired it is generally preferable to use a white cement for the finishing coat. By using coloured sand or stone chips it is possible to obtain delicate and interesting colour effects which are absolutely permanent. With the use of larger coloured aggregates the stucco effect is obtained either by throwing chips or pebbles on to the finish coat of stucco, or by mixing the stone with the finish and exposing it afterwards by scrubbing or acid treatment.

The first method is by casting on to the finish coat, while it is still soft, coloured stone chips or pebbles. Various



HOUSE AT STRATFORD-ON-AVON, FINISHED IN WHITE CEMENT-STUCCO.

[Mr. L. L. Dussault, F.R.I.B.A., Architect.

sizes may be used as desired, but usually ¼-in. chips are found to stick more readily and give the best appearance. For this work about 15 lbs. of the aggregates are required per sq. yd. of surface. The man who applies them should follow immediately behind the plasterer, and the chips should be thrown forcibly against the wall and then lightly pressed in with a wooden float so as to be firmly imbedded.

In the second, or integral, method the mixture for the finish coat should be 1 part white or light-coloured cement, 1½ parts white sand and 1½ parts of the aggregate running in size from ⅛ to ¼ in. Usually the walls can be washed down within 24 hours after the finish coat is placed. The use of too much water should be avoided, as it is apt to penetrate and loosen the entire coat. A damp sponge serves very well to wash the cement from the surface of the pebbles. If the cement has hardened too much to be removed easily, ¼ part muriatic acid should be added to the water and the surface washed down briskly and afterwards sprayed with clear water to remove all traces of the acid.

We are indebted for the above notes to a booklet issued by the Atlas Portland Cement Company of the United States, manufacturers of "Atlas White" Portland Cement, whose representative in this country is Mr. Frederic Coleman, of Regent House, Regent Street, W.1.

APPLICATION OF STUCCO.

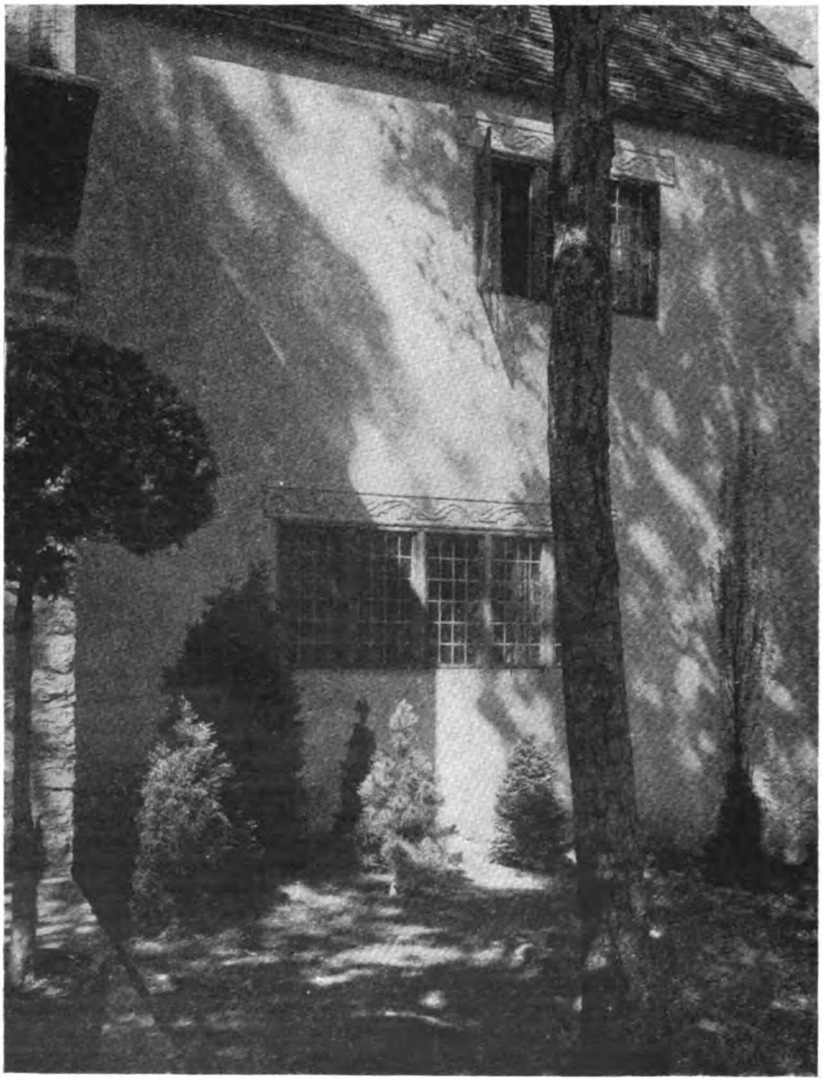
The following abstract from a report of the Committee on Concrete Surfaces of the American Concrete Institute gives some useful general notes on the application of cement-stucco :—

Design.—Whenever the design of the structure permits, an overhanging roof or similar projection is recommended to afford protection to the stucco. Stuccoed copings, cornices and other horizontal surfaces should be avoided whenever possible. All exposed stucco surfaces should shed water quickly, and whenever departure from the vertical is necessary the greatest possible slope should be adopted. Stucco should not be run to the ground if other treatment is possible. Should the design of the structure require this treatment, the backing should be of a material which will provide a good mechanical bond for the stucco, and should be thoroughly cleaned before plastering. Unless special care is taken thoroughly to clean the base and each plaster coat from dirt and splash before the succeeding coat is applied, failure of the stucco may result.

Flashing.—Suitable flashing should be provided over all door and window openings wherever projecting wood trim occurs. Wall copings, cornices, rails, chimney caps, etc., should be built with ample overhanging drip groove or lip and water-tight joints. If copings are set in blocks with mortar joints, continuous flashing should extend across the wall below the coping and project beyond and form an inconspicuous lip over the upper edge of the stucco. Continuous flashing with similar projecting lip should be provided under brick sills. This flashing should be so installed as to ensure protection against interior leakage. Cornices set with mortar joints should be provided with flashing over the top. Sills should project well from the face of the stucco and be provided with drip grooves or flashing as described above for brick sills. Special attention should be given to the design of gutters and downspouts at returns of porch roofs where overflows will result in discoloration and cracking. A 2-in. strip should be provided at the intersection of walls and sloping roofs and flashing extended up and over it, the stucco being brought down only to the top of the strip.

Preparation of Original Surface.—All roof gutters should be fixed, and downspout hangers and all other fixed supports should be put in place before the plastering is done in order to avoid breaks in the stucco. Metal lath and wood lath should be stopped not less than 12 in. above grade to be free from ground moisture. All trim should be placed in such manner that it will show its proper projection in relation to the finished stucco surface, particularly in overcoating.

Before applying the cement stucco, masonry, brick or tile walls should be roughened on the surface, the joint raked, and the surface brushed free from all dirt, dust, and loose particles, and wetted to such a degree that water will not be rapidly absorbed from the plaster, but not to such a degree that water will remain standing on the surface when the plaster is applied. Old brick walls which are to be overcoated should have all loose, friable, or soft mortar removed



[Mr. B. Tuttle, Architect.

PLAIN SAND-FLOAT FINISH.

CEMENT-STUCCO FINISH: HOUSE AT BRONXVILLE, U.S.A.

from the joints, and all dirt and foreign matter should be removed by hacking, wire brushing or other effective means. Surfaces that have been painted or waterproofed should be lathed with metal lath before overcoating.

Monolithic concrete walls should preferably be rough and of coarse texture for the application of stucco. Walls of this type should be cleaned and roughened, if necessary, by hacking, wire brushing, or other means. The surface of the concrete should be brushed free from all dust, dirt and loose particles, and should be wetted to such a degree that water will not be rapidly absorbed from the plaster, but not to such a degree that water will remain standing on the surface when the plaster is applied.

For frame walls studs spaced not to exceed 16-in. centres should be run from foundation to rafters without any intervening horizontal members. The studs should be tied together just below the floor joists with 1 in. by 6 in. boards which should be let into the studs on their inner side, so as to be flush and securely nailed to them. These boards will also act as sills for the floor joists, which, in addition, should be securely spiked to the side of the studs. The corners of each wall should be braced diagonally with 1 in. by 6 in. boards let into the studs on their inner side, and securely nailed to them.

STUCCO INGREDIENTS.

The cement should meet the requirements of the standard specifications for Portland cement.

Fine aggregate should consist of sand, or screenings from crushed stone or crushed pebbles, graded from fine to coarse, passing when dry a No. 8 screen. Fine aggregate should preferably be of silicious materials, clean, coarse, and free from loam, vegetable, or other deleterious matter.

Only mineral colours should be used which are not affected by lime, Portland cement, or other ingredients of the mortar, or the weather.

The importance of proper and thorough mixing of the ingredients of the mortar cannot be too strongly emphasised. Machine mixing is in all cases to be recommended in preference to hand mixing. The use of hair or fibre is optional, and when used, the method of incorporation should be such as to ensure good distribution and freedom from clots.

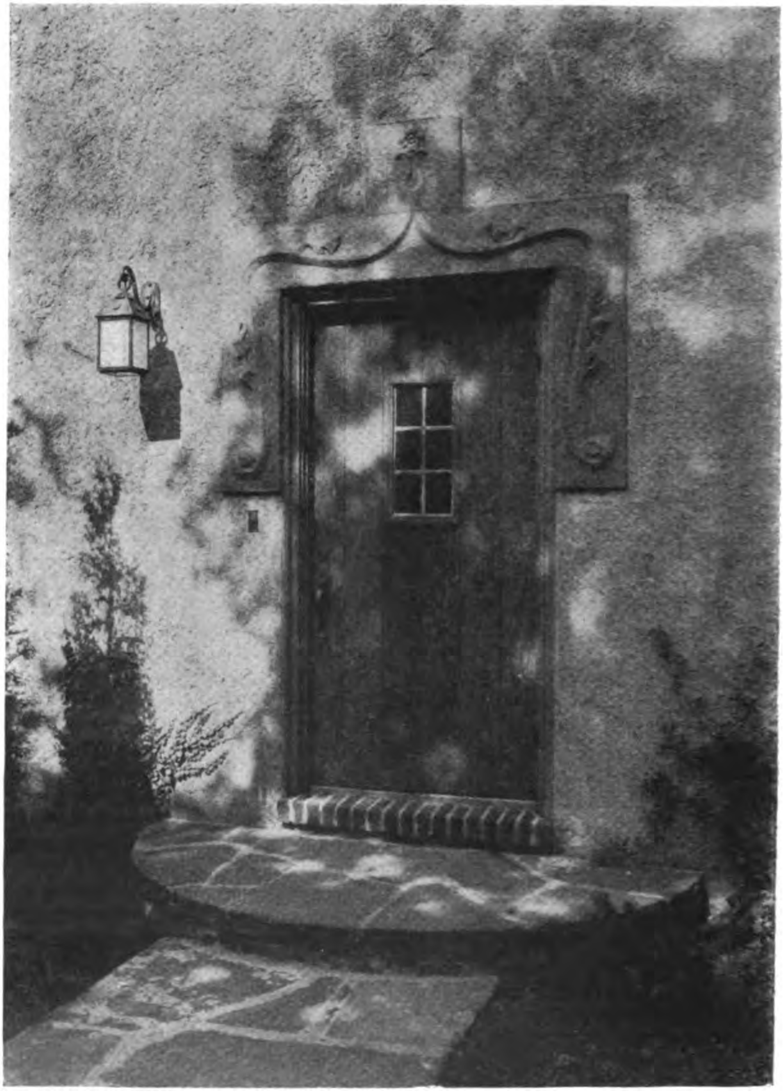
The ingredients of the mortar should be mixed until thoroughly distributed, and the mass is uniform in colour and homogeneous. The quantity of water necessary for the desired consistency should be determined by trial, and thereafter measured in proper proportion.

The period of machine mixing should be not less than 5 minutes after all the ingredients are introduced into the mixer. Hand-mixing should be done in a watertight mortar box, and the ingredients mixed dry until the mass is uniform in colour and homogeneous. The proper amount of water should then be added and the mixing continued until the consistency is uniform. Mortar which has begun to stiffen or take on its initial set should not be used. Only sufficient water should be used to produce a good workable consistency. The less water the better the quality of the mortar within working limits.

The scratch coat is the first applied, and its purpose is to form an intimate bond and a secure support for the body of the stucco. On metal lath it also serves as a protective coat, and it should therefore be strong and not too lean. Hair or fibre should not be used when the space behind the lath is to be filled, and is probably not a necessary ingredient in any case. The thickness of the scratch coat should average about ¼ in. over the face of the lath.

The function of the second coat (commonly called the " straightening " coat) is to establish a true and even surface upon which to apply the finish. It forms the body of the stucco, and must fill the hollows and cover the humps of the scratch coat. For this reason an average thickness of ⅜ in to ½ in. will usually be required. The two coats are sometimes combined in two-coat work, which is permissible when the base upon which the stucco is applied is fairly true and even, or when, on account of cost consideration, the best obtainable finish is not required. It is difficult, however, to obtain a satisfactory finish on a coat which runs ½ in. or more in thickness, since the tendency of a heavy coat to " bag " and slip is likely to produce an uneven surface.

The finish coat serves only a decorative purpose and has no structural value. Its



[Mr. J. Gregory, Architect.

STIPPLE SURFACE MADE IRREGULAR BY IRREGULAR APPLICATION OF STIPPLING BRUSH.

CEMENT-STUCCO FINISH: HOUSE AT SPUYTEN DUYRIL, NEW YORK.

function is solely to provide an attractive appearance, and any mixture or any method of application that may detract from the appearance, or in any way injure its permanency, should be avoided. The finish coat should be as thin as possible consistent with covering capacity, and may vary from ⅛ to ⅜ in. in thickness, depending upon the type employed.

First-class stucco should be three-coat work, each coat serving its own particular purpose. The bond between the first and second coats needs to be strong in order to carry the weight of the body of the stucco, and for this reason it is considered preferable to apply the second coat the day following the application of the scratch coat. Except in dry or windy weather, little wetting of the first coat should be necessary when the second coat is to follow within 24 hours. A slight degree of absorption or " suction " in the first coat is probably better than complete saturation, for the second coat, as well as the others, is necessarily mixed with a larger quantity of water than it requires for maximum strength. The removal of a portion of this excess water by the suction of the undercoat not only improves the quality of the coat but also ensures a better bond by tending to draw the fine particles of the cement into the pores and interstices of the undercoat.

Whereas the interval between the first and second coats should be relatively short, the interval before applying the finish coat should be as long as permissible under the conditions of the work, in order to enable the body of the stucco to obtain its initial shrinkage and a nearer approach to its final condition of strength and hardness before being covered with the surface coat. The bond of the latter needs to be intimate rather than of maximum strength, and if the body of the stucco has been allowed to set and harden thoroughly it may be assumed that there is less liability of volume changes in the undercoats to disturb the finish coat. A week or more should elapse between the application of the second and finish coats.

The finish coat should be applied over a damp but not saturated undercoat, for excess water is likely to injure the bond seriously. Certain types of finish such as the wet mixtures used for sand spraying, or for the " spatter dash " finish, may preferably be applied to a fairly dry undercoat, since suction must be depended upon to prevent streakiness and muddy appearance. The fact that finishes of this type applied in this manner may set and dry out with little strength is not serious ; they gradually attain sufficient hardness with exposure to the weather.

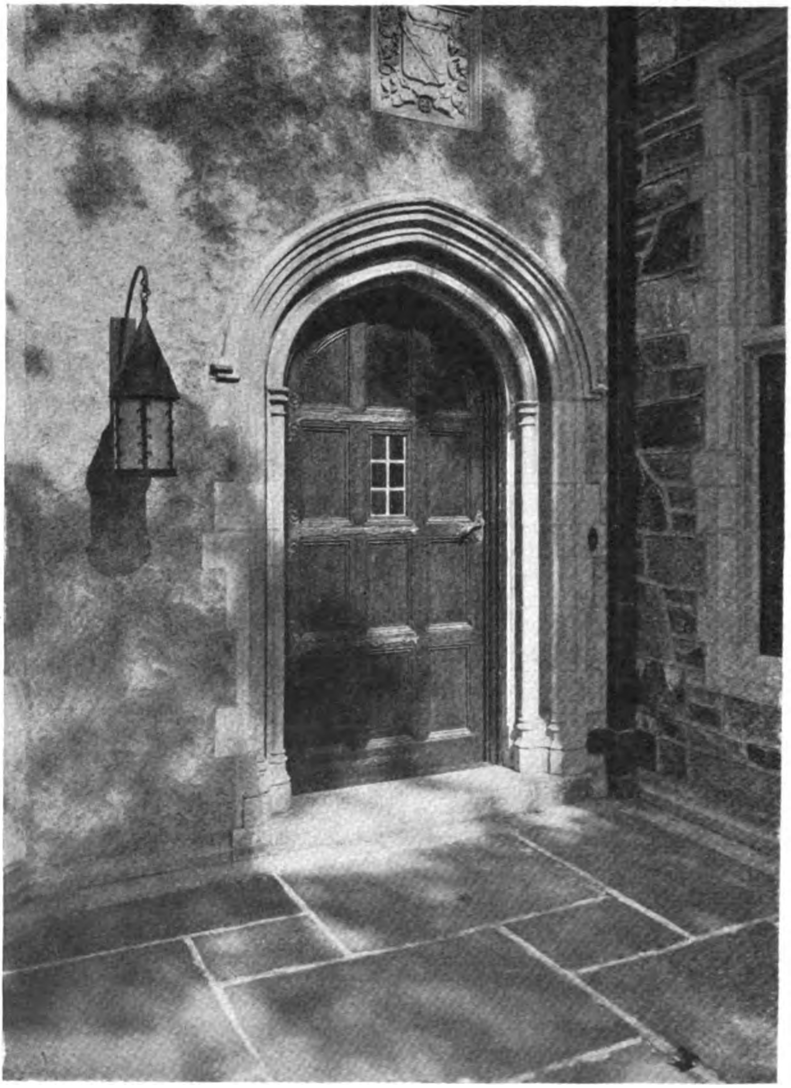
Curing of the undercoats by sprinkling and protection of finish coats against the sun, wind, rain and frost, by means of tarpaulins is always to be recommended, but is not necessary providing reasonable precautions are taken. The application of cement stucco in freezing weather should be avoided, and, in fact, temperature slightly above the freezing point may allow frost to form on a damp wall. The application of stucco under such conditions is likely to result in failure.

All coats should contain not less than 3 parts of fine aggregate to 1 part of Portland cement. The plastering should be carried on continually in one general direction without allowing the plaster to dry at the edge. If it is impossible to work the full width of the wall at one time, the joining should be at some natural division of the surface, such as a window or door.

The first coat should thoroughly cover the base on which it is applied and be well trowelled to ensure the best obtainable bond. Before the coat has set it should be heavily cross-scratched to provide a strong mechanical key. The second coat should be applied whenever possible on the day following the application of the scratch coat. The first coat should be dampened if necessary, but not saturated, before the second coat is applied.

The second coat should be brought to a true and even surface by screeding at intervals not exceeding 5 ft., and by constant use of a straightening rod. When the second coat has stiffened sufficiently it should be dry floated with a wood float and lightly and evenly cross-scratched to form a good mechanical bond for the finish coat. The day following the application of the second coat, and for not less than three days thereafter, the coat should be sprayed or wetted at frequent intervals and kept from drying out.

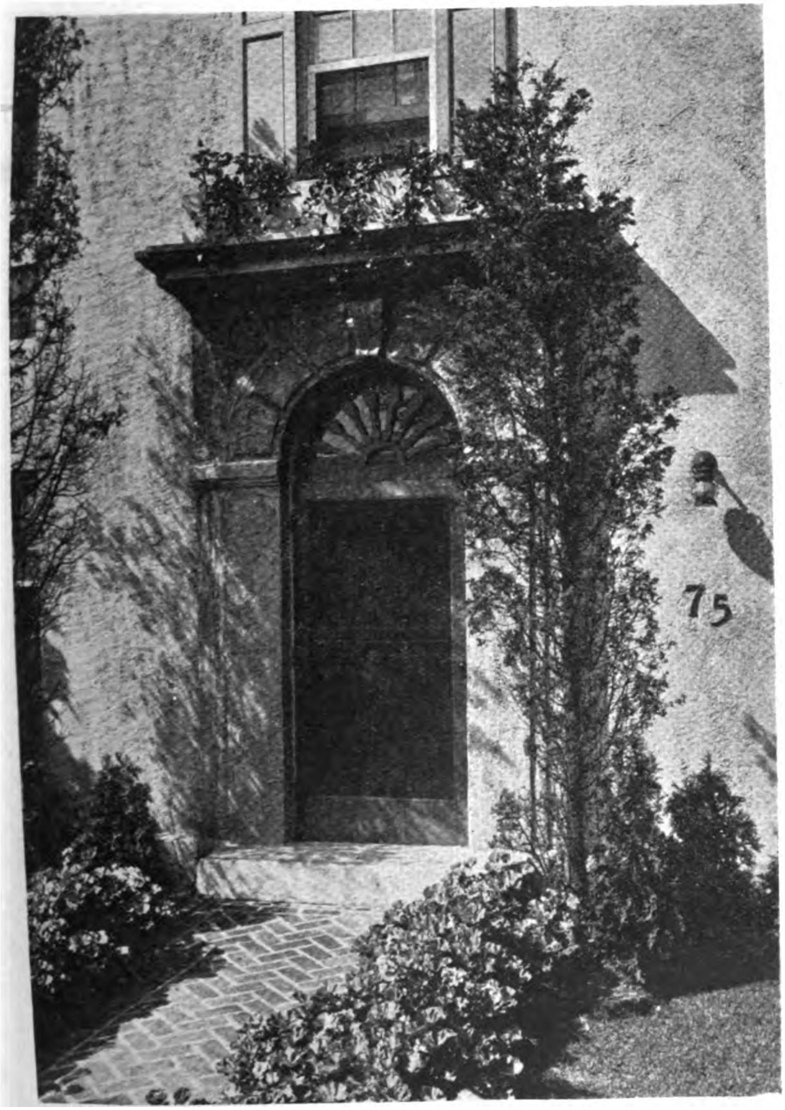
The finish coat should be applied not less than a week after the application of the second coat, by the methods already described.



[*Messrs. Rossiter and Muller, Architects.*

EFFECT OBTAINED BY USING HEEL OF TROWEL ON FINISHED SURFACE.

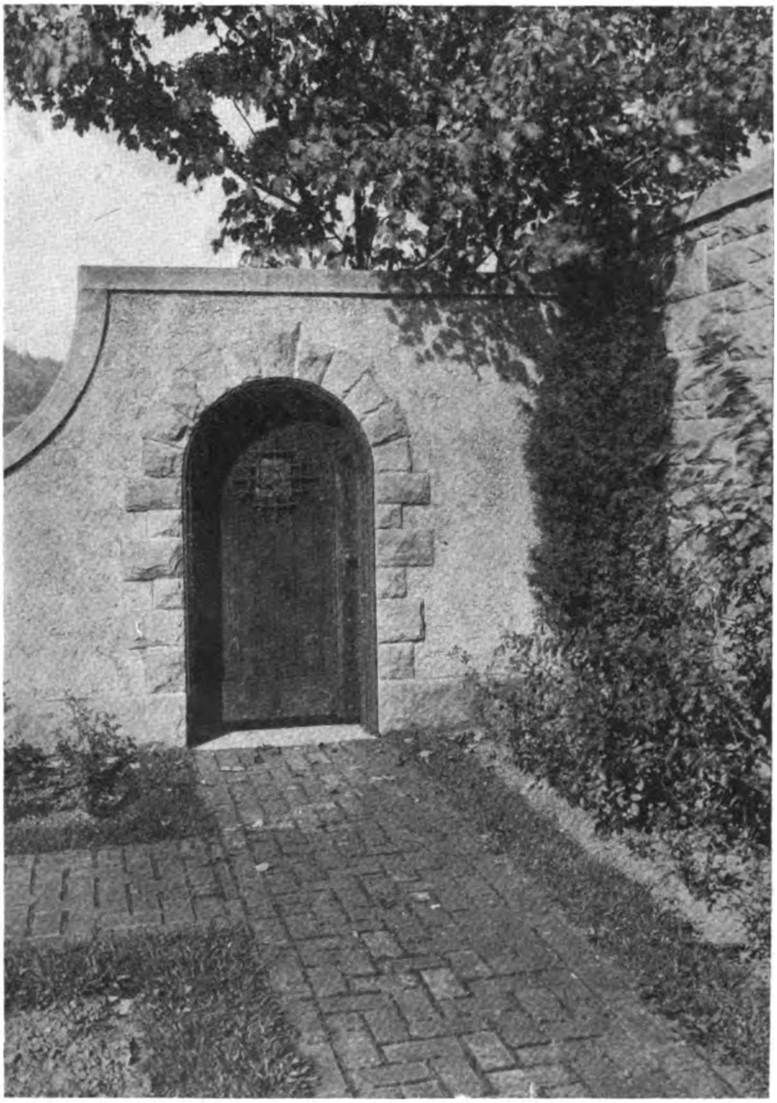
CEMENT-STUCCO FINISH: HOUSE AT NEW HAVEN, CONN., U.S.A. (*See p.* 39.)



[*Mr. H. Bottomley, Architect.*

Effect Obtained by Tearing Finished Surface with Bottom Edge of Trowel.

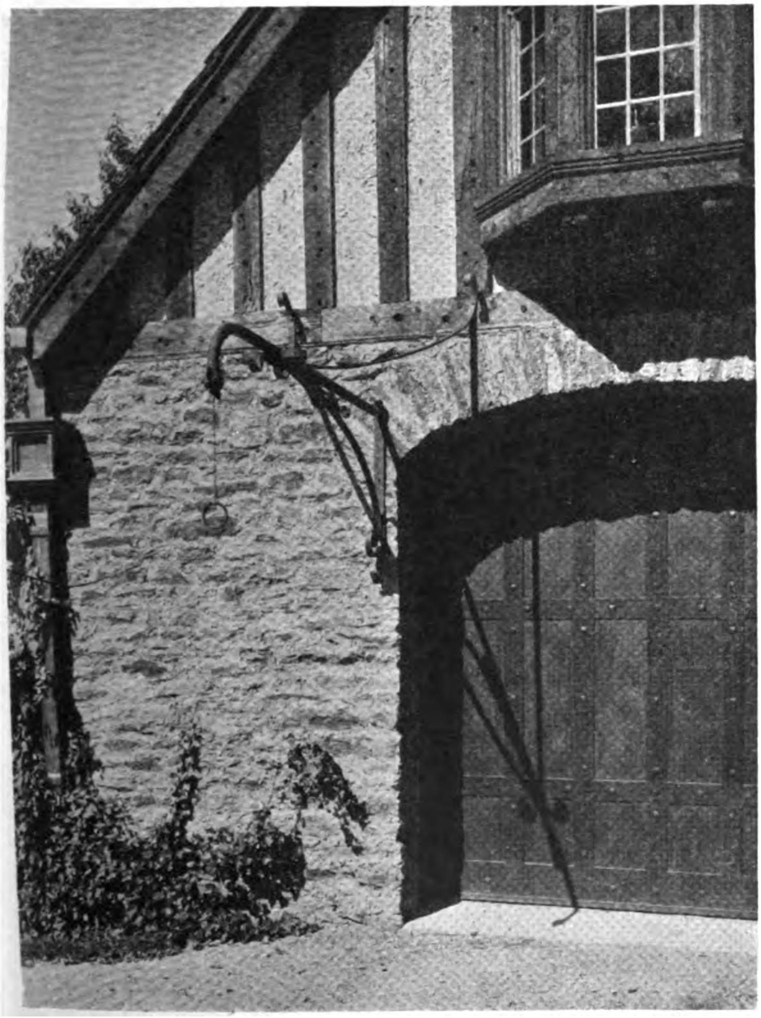
CEMENT-STUCCO FINISH: HOUSE AT FOREST HILLS, NEW YORK. (*See p.* 39.)



[Mr. A. J. Bodker, Architect.

EFFECT OBTAINED BY APPLYING IRREGULAR DABS OF LOOSE MORTAR TO THE SURFACE FINISH.

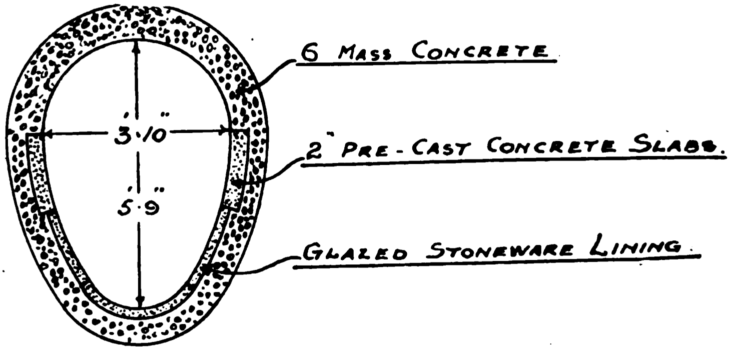
CEMENT STUCCO FINISH: GARDEN AT LAIDLAW, PENN, U.S.A. (*See p.* 39.)



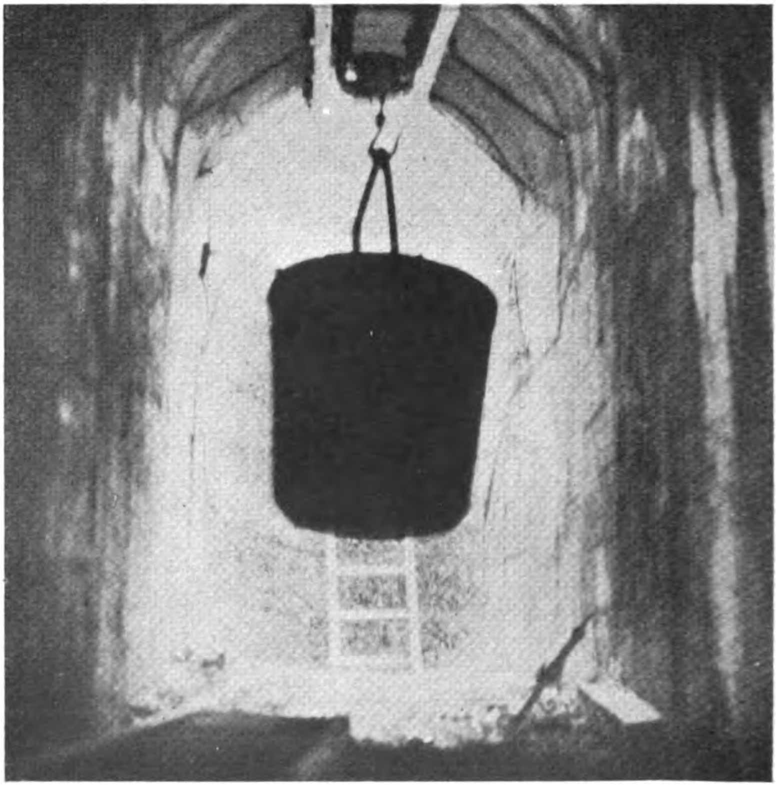
[Mr. H. C. Morse, Architect.

Mortar Between Timbers Finished with Bare Hand.

CEMENT-STUCCO FINISH: HOUSE AT NEW ROCHELL, U.S.A. (See p. 39.)



Cross Section.



Showing Skip Travelling from the Tunnel to Shaft.

CONCRETE SEWER AT LUTON. (*See p.* 51.)

CONCRETE SEWER AT LUTON.

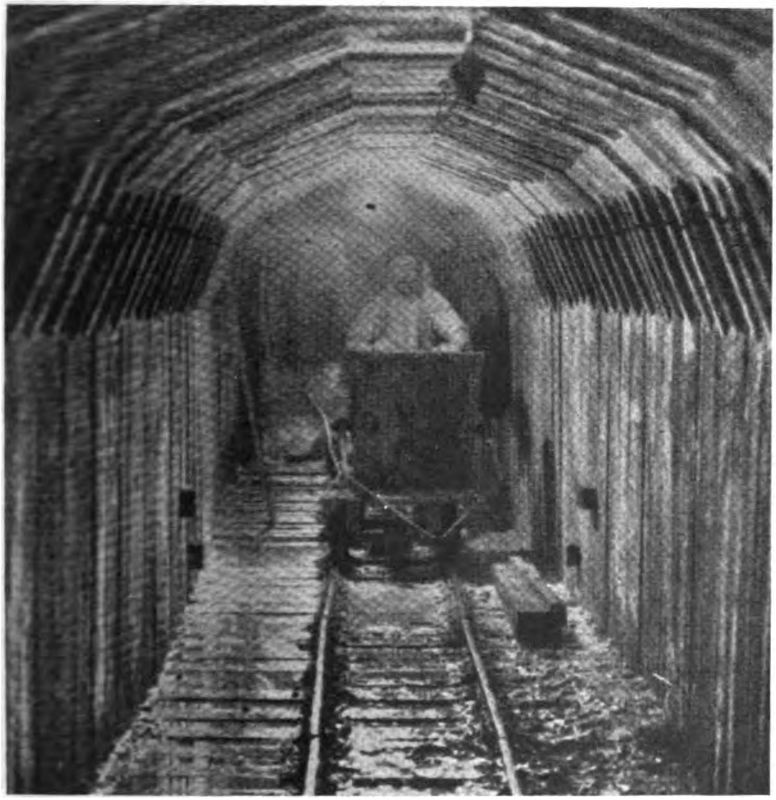
It is anticipated that within the course of this month the work will be completed of constructing a new main sewer through the centre of the town of Luton. The work was put in hand as a relief work, and has been carried through from beginning to end solely by labour obtained from the Labour Exchange, almost the whole of which was unskilled.

The sewer is just over one mile in length, and consists of about three-quarters of a mile of 5 ft. 9 ins. by 3 ft. 10 ins. egg-shape sewer, and a quarter of a mile of 4 ft. 6 in. by 3 ft. egg-shape sewer.

The sewer traverses the most congested streets of the town, but the work has been carried out for the most part without any disturbance of street surfaces, being in tunnel at depths varying from 12 ft. to 33 ft. to invert. Most of the tunnelling was through somewhat treacherous ground, and had to be timber-sheathed with strong framing.

The construction of the sewer is somewhat unusual. It is formed entirely in concrete, with the exception that the invert and portion of the sides are lined with special glazed fireclay blocks. In the larger size these fireclay blocks extend to a height of about 2 ft. above the invert, and above them the sides of the sewer up to springing line are formed of pre-cast concrete slabs. The arch of the sewer is in mass concrete.

It has been found that a sewer of this character can be constructed fairly quickly with unskilled labour, apart from the setting of the blocks, and this latter operation can go forward at a very con-



Concrete Sewer at Luton: Showing Timbering.

siderable pace, two or three skilled men being able to keep pace with fully a hundred unskilled men.

The final cost of the work is not obtainable as the job is not yet completed, but it is confidently expected that it will be shown this type of construction is comparatively cheap.

A great deal of clinker has been used in the concrete backings, but all the more important concrete is made with natural gravel obtained in the neighbourhood. There seems to be very little difficulty in producing a concrete with this gravel, which is quite water-tight.

All the work in tunnel was carried out with electric light, arrangements for a supply of electricity being made at each pit.

The work is being carried out under the direction of the Borough Engineer and Surveyor, Mr. J. W. Tomlinson, A.M.Inst. C.E., M.Inst.M. and C.E., M.S.A., to whom we are indebted for the accompanying illustrations.

"THE CONCRETE YEAR BOOK, 1924."

THE large number of inquiries we are continually receiving for names of makers of different specialities, addresses of firms and engineers, etc., have convinced us that there is a great need for a complete directory of the many branches of the concrete industry. It is, in fact, an anomaly that a growing industry which has already reached such large proportions should be without its directory, and we have therefore endeavoured to fill this gap by the publication of the first edition of "The Concrete Year Book," edited by Oscar Faber, O.B.E., D.Sc., and the Editor of Concrete Publications, Limited. This volume is a Handbook and Directory for the Concrete Industry, and should be of considerable value to all interested in the many branches of that industry.

The first part of the book, the Handbook Section, consists of 130 pp. of special articles dealing with such subjects as the economical use of cement, essentials in the production of good concrete, proportioning and grading of aggregates, concrete floors, concrete roads, concreting in cold weather, and other aspects of the uses of concrete. A specially-prepared series of tables for reinforced concrete design is also included. Another feature is a bibliography of all books dealing with reinforced concrete and allied subjects.

The Directory Section, occupying 60 pp., forms a complete guide to the industry and is classified under different headings, including Consulting Engineers who Specialise in Reinforced Concrete, Reinforced Concrete Designing Firms, Public Works Contractors who Specialise in Concrete Construction, Concrete Flooring Specialists, Suppliers of Aggregates and Sand, Artificial Stone Manufacturers, Manufacturers of Colouring Materials for Concrete, Manufacturers of Machinery and Plant for Concrete and General Constructional Work, Manufacturers of Concrete Products, Manufacturers of Reinforcement, Contractors for Concrete Roads, Manufacturers of Proofers and Hardeners for Concrete, Piling Contractors, Manufacturers of Asbestos-Cement Products, Concrete Testers, etc. No pains have been spared to make the Directory Section as complete and accurate as possible.

The third section of the publication is a Catalogue of the industry, containing within 150 pp. full descriptions of the businesses, manufactures, or products of some 120 different firms connected with the industry.

The volume, which is strongly bound, is published by Concrete Publications, Ltd., Publishing Department, 4 Catherine Street, Aldwych, W.C.2, price 3s. post free, and copies may be ordered by filling in the order form on p. 64

CONCRETING IN COLD WEATHER.

Some useful hints on methods of laying and protecting concrete in cold weather are given in a booklet received from the American Portland Cement Association, from which we take the following :—

Since warmth and moisture are required for the proper hardening of concrete, cold weather work should be planned with those necessities in view. Both the mixing water and the aggregates should be heated. The cement forms but a small portion of the concrete and need not be heated, but it is well to keep it in a warm place for a few hours before it is used.

The nearer the temperature of the water is to the boiling point the better will be the results because it will take longer to dissipate the heat and cool the mixture. There are several types of water heaters that can be used, but the most common method of heating is to pass steam into the water tank. The concrete should be mixed with the least amount of water practicable to produce a workable, plastic mixture. An excess of water must be carefully avoided.

HEATING AGGREGATES.

Many methods are used for heating aggregates. A simple method is to use a length of iron pipe, an old boiler, or any metal cylinder over which the sand, broken stone, or pebbles can be piled, and in which a fire can be built. Care must be taken to heat the fine and coarse aggregates separately in order to avoid premixing them in wrong proportions. As this method entails rehandling the aggregate, and as the aggregates nearest the heater may be affected by excessive heat, the use of steam pipes is generally preferred.

Steam heating is a more expensive method and requires a steam boiler, but on large jobs this method is usually advantageous because the steam may also be used for other purposes. A practical method is to use a perforated steam pipe with a pointed end which can be worked into the piles of aggregates. To reduce loss of heat the piles of aggregates should be covered with tarpaulins.

If the materials are heated as above outlined, and the concrete is deposited immediately after mixing, its temperature when placed in the forms will be around 80 deg. F., and if care is taken to prevent too rapid loss of this contained heat the concrete will harden properly. The early stages of hardening may be even more rapid than under ordinary conditions.

HEATING THE FORMS.

The forms must be free from snow, ice and frost, and should also, if possible, be reasonably warm, especially in the case of metal forms, which will absorb heat from the concrete rapidly. Live steam is an effective agent for cleaning ice and snow from the forms, and warming them. It should be used just before the concrete is placed.

PRECAUTIONS WHILE HARDENING.

A rapid loss of contained heat must be prevented. The concrete should be protected while hardening so as to maintain the warm, moist condition essential for the rapid development of strength. There are many methods of doing this : the most common is an enclosure of canvas or tarpaulins. In mild weather this alone may be sufficient, but when the temperature drops below the freezing point some means should be provided for heating the enclosure. Steam escaping from perforated steam pipes around the concrete will give the best results, because the steam saturates the air and prevents evaporation of moisture from the concrete.

Coke salamanders (or fire buckets) are often used when steam is not available to supply warmth to the enclosure, but large pans of water should be placed over them in order to provide as much moisture in the air as possible. Care should be taken not to have these fires so close to the concrete as to dry it out in spots. An even temperature of at least 60 deg. F. should be maintained at all times in all parts of the enclosure. To maintain this temperature within a properly housed enclosure during cold weather, with good coke properly handled, one salamander will be required for every 300 to 500 sq. ft. of floor area.

The most common practice is to build enclosures of tarpaulins, over-lapped so as to prevent rapid escape of heat, about two stories being enclosed at one time. Undoubtedly a better method was the one followed in the winter of 1922–1923 in the construction of the Keenan Hotel, a 14-story reinforced concrete building in Fort Wayne, Ind., where five stories were enclosed at one time ; this prolonged the length of time during which freshly placed concrete was kept warm and resulted in complete hardening before the protection was removed.

A more substantial form of protection is a complete wooden enclosure, built under a complete enclosure of tarpaulins supported on frame-work. Complete enclosures necessarily cost more than temporary ones that protect only a few stories at a time ; their great advantage, however, consists in the fact that they protect the workmen of all trades and speed up the work from beginning to end. Furthermore, when once built they require no shifting.

The complete enclosure idea was followed in the construction of the three-span reinforced concrete arch bridge over the Little Goose River, in Wyoming. A large tent covered the entire bridge site and permitted construction during severe winter weather when the stream was solidly frozen over. The cold weather, in fact, eliminated trouble from running water and actually speeded up the progress of the work. Fires were kept going in stoves with smoke outlets extending through the top of the tent. During the placing of concrete a heavy snow storm, followed by severe cold that lasted several days, tested the effectiveness of the tent, and the protection proved equal to the emergency.

For retaining walls and similar structures a light roofing-paper envelope placed outside the forms with steam pipes at the bottom has proved satisfactory.

PROTECTIVE COVERINGS.

When it is warm during the day with a temperature drop close to the freezing point at night, floors, pavements and foundations are often protected by covering with straw, hay or other material with satisfactory results, but such covering should not be relied upon during protracted low temperatures.

Even though the outdoor temperature may not drop to freezing, protection is necessary to prevent the concrete from losing the heat introduced by heating the materials, and ensure proper hardening. At low temperatures the heat developed by the chemical reaction of the cement and water is too small to be safely relied upon except in large masses underground, and even in those cases the materials should be heated and the surface protected.

Thin structural members and floors have such a large surface area in proportion to their size that the heat within the concrete is dissipated rapidly, and therefore protection must be provided. Recent inspection of several concrete floors placed during the winter of 1922–1923 disclosed the fact that the top surface was inadequately protected after being placed. On one floor in particular it is known that the top surface was placed during cold weather and no protection whatever was provided. It was permitted to freeze almost immediately after it was placed, and it is probable that it froze and thawed several times before it hardened. The result was an unsatisfactory wearing course which in many places must be removed and replaced. Work of this kind should be protected with canvas, supported slightly above the surface, and with live steam forced under the canvas. The steam has the excellent characteristic of providing both heat and moisture, both essential in obtaining the best results in the hardening of concrete.

USE OF SALT OR CALCIUM CHLORIDE.

The practice of adding " anti-freezing " compounds such as sodium chloride (common salt) or calcium chloride solutions to the concrete mixture is not generally recommended. Under no circumstances should they be depended upon to prevent freezing below 22 deg. Fahr., and they should never be considered substitutes for protection and heating.

Calcium chloride in quantity not exceeding 4 per cent. by weight of the mixing water is a better anti-freezing agent than common salt. It accelerates the hardening of concrete to some extent, while salt retards hardening. Salt has a tendency to corrode reinforcing steel, and may cause efflorescence, which is unsightly on exposed surfaces.

Even if anti-freezing solutions are used, the aggregates and mixing water should be heated to remove ice or frost.

REMOVAL OF FORMS.

Too early removal of forms is always to be guarded against even during construction in favourable weather, and great caution should be observed in placing loads upon cold weather concrete. Especially is this true of walls, roofs and floors above ground, which carry loads other than their own weight.

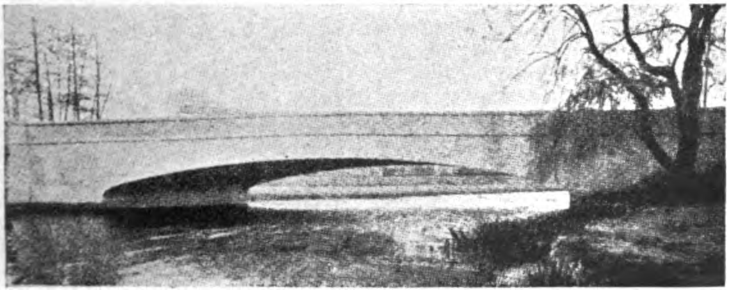
Before removing forms the concrete should be examined to see that it has properly hardened and not frozen. A reliable test is to apply heat to the surface by means of a blow torch or a jet of hot water or steam against it. Frozen concrete will be disclosed by softening as it thaws out, but if properly hardened, the concrete will be unaffected by the application of heat.

HIGHLY-POROUS CONCRETE.

An exceptionally porous concrete has just been produced by A. Erikssen, of the Royal Technical School, Stockholm, who terms it "Gasbeton." This material has a similar colour to cement, but its texture is full of pores and closely resembles pumice stone. It is made by mixing 2 parts of cement and 3 of chalk with a small proportion of powdered aluminium, which produces bubbles of gas when the material is mixed with water. The pores occupy no less than 75 per cent. of the total volume of the material, which has a density not exceeding 42 lb. per cu. ft., a crushing strength after 6 weeks of 350–420 lb. per sq. in., and a thermal conductivity of 0·2. Slabs made of this material can easily be sawn into any desired shape. This material must be coated with ordinary concrete for external wall-surfaces, but for light partitions it appears to be very suitable, cheap and convenient.—*Zentralblatt der Bauverwaltung.*

CONCRETE BRIDGE AT BERGSDORF.

The accompanying illustration shows a particularly neat bridge, of 75 ft. span, which has recently been built over the river Bille near Bergsdorf. It was designed to carry with safety a 30-ton wagon fully loaded. The bridge is supported on piles. The details of construction do not call for any special comment. We are indebted to *Beton u. Eisen* for our illustration.



Concrete Bridge at Bergsdorf.

BOOK REVIEWS.

Handbuch für Eisenbetonbau. 3rd Edition. 5th Volume: Reservoirs, Tubes, Canals, Aqueducts. By Dr. F. Emperger.
Berlin: Wilhelm Ernst & Sohn. 409 pp. 191 Illustrations. Price 13s. 10*d*.

THIS book is one of the 14 volumes that go to make up the hand book which is so well known and widely used on the Continent. Like all books by the same author, this volume shows an exceedingly thorough treatment of the subject in all respects, both from the theoretical and the practical point of view, and the reader feels after perusing any of the chapters that there cannot be much more to be said on the subject.

The necessity for the appearance of a new edition after the second one in 1910 is explained by the enormous growth of the use of reinforced concrete for this particular branch of engineering, and the wealth of new data and valuable experience that have been collected since then make the last edition a most up-to-date text book. The question of the action on concrete of the many different technical chemicals it is desired to store in reservoirs and tanks is given special prominence, and much excellent advice may be gathered from the chapter dealing with this aspect of tank construction. Also in regard to the statical calculation of reservoirs, tanks, etc., the reader is given the full advantage of the latest methods that are based solely upon the theory of elastic deformations, yet set forth in a form that enables most readers with a little knowledge of mathematics to follow them.

In the introductory chapters the question of making concrete proof against leakage of water or other liquids is treated from three points of view—making the concrete itself good enough to withstand liquid pressure, obtaining impermeability of the concrete by the addition of various waterproofing ingredients, and relying upon coatings of an impenetrable nature to secure water-tightness. An extensive list of different waterproofing materials is given, with such data as has been obtained from the makers as to composition, quantity required, behaviour in actual practice, etc. The best part of the book, at any rate from the designer's point of view, is the chapter dealing with examples of work actually executed in various parts of the world; it gives a very interesting and complete description of each of the examples, with full particulars of the execution, details of reinforcement, sections, elevations, photographs, etc.; in the chapter dealing with water towers will be found a particularly interesting collection of pictures and details of work belonging to this section.

To the engineer familiar with the language, and—on account of the excellent illustrations—even to those who do not master it, the book should be a most valuable addition to the technical library. —R. N. S.

The Road. By Hilaire Belloc.
Manchester: Charles W. Hobson. 218 pp. Price 15s.

INLAND travel and the transportation of goods from one spot to another are problems which have had to be faced continually from the beginning of time—from the period when requirements were limited to a track from the cave to a spring and a forest or other source of food supply, to the present age of motor-lorries, tramcars, and 12-ton steam wagons and trailers; from the time when no one thought of travelling at a greater pace than his own legs or those of a horse would carry him, to the day of the motor-car speeding on a track at over a hundred miles an hour. And perhaps it is the fact that there has always been a road problem that is responsible for the half-hearted measure in which it is being attacked to-day: difficulties from which we are never free are prone to be neglected. Throughout the ages, with the exception, perhaps, of the military roads of the Romans, there has been no apparent haste to reconstruct the road system to meet requirements, and one wonders how much of the road work now going on would have been tackled but for the necessity of finding some means of relieving unemployment rather than to a thorough realisation of the absolute necessity of bringing the roads into line with the demands of modern traffic if the trade and commerce of the country are not to suffer. A perusal of Mr. Belloc's most interesting book shows that roads have always been sadly lacking in their ability to carry the traffic of their time, and that the country has suffered in consequence.

The reason is, of course, the obvious inability to foresee developments in methods of transportation, and a natural disinclination, when works of reconstruction are undertaken to meet the requirements of the time, to incur additional expenditure to meet conjectural conditions which in any case might not materialise within the lifetime of those undertaking, and paying for, the work. Who, not so many years ago, could say that half the width of the main urban thoroughfares would be taken up with tracks for tramcars, or that two or three hundred 'buses would pass the busy crossing places each hour? In the wide arterial roads now being built, there is every possibility that they will suffice for at least another generation, but the excusable lack of foresight when city streets were laid out has resulted in a state of congestion which the increased value of land has made almost impossible of remedy without incurring enormous cost.

The author has extensively studied his subject in all parts of the world, and throughout this book he emphasizes the influence of transport facilities on trade and commerce; of the present problems in this country he says: "We have come to a crisis to-day in the history of the English road. It must be changed, or supplemented under peril of such congestion as will strangle travel and interchange." . . . "We need five things: (1) A very strong foundation, upon which depends—(2) a permanently good surface; (3) the avoidance of sudden curves; (4) great width; and (5) provision of crossing places on wide roads carrying fast traffic." Everyone will agree with these fundamental principles, although the magnitude and cost of the task, which is nothing less than the rebuilding of the whole of the main road system of the country, will necessarily mean that such an undertaking must be spread over a long period of years.

This well-produced volume, illustrated with a number of charming drawings, will be full of interest not only to those directly concerned with the construction of roads but also to students of history, for its roads are so intimately bound up with the history of the country, and, as the author shows, often directly responsible for it, that an account of the roads of a country cannot fail to be a history of politics and commerce as well. The author traces the development of the road system in this country from the earliest times in a very interesting and readable manner, without going into the question of construction, which, as he says, is a matter for technical rather than literary men.—H.C.

CORRESPONDENCE.

DESIGN OF REINFORCED CONCRETE SLABS.

Sir,—When working out some examples of reinforced concrete slabs supported on four edges according to the formula recommended by the French Government, i.e. $S = \frac{L^4}{L^4 + 2B^4}$, I came across a useful relationship which considerably facilitates calculation of these slabs.

Putting this relationship in the form of a Rule:—"The principal bending moment in a rectangular slab supported on four sides, whose breadth is over half its length, is equal to that of a slab supported at the ends only whose length (i.e. span) is equal to larger side of rectangular slab × 0·577.

This gives results very near to those worked out by formula, and enables slab-tables to be used; the secondary reinforcement can usually be estimated without actual calculation.

A. J. Mitchell.

Alexandria, Egypt.

QUESTIONS AND ANSWERS RELATING TO CONCRETE.

Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—Ed.

REINFORCED CONCRETE BEAMS.

Question.—You will do a great service to the designers in the field of reinforced concrete by publishing in your valuable magazine, in detail as far as possible, a discussion on the following contested point.

Some designers hold that the main beams, carrying the subsidiary beams, cannot be designed as T-beams, but should be designed as rectangular beams without taking advantage of the slab over the beam. They agree that the slab already acting as flange to the subsidiary beams (which are designed as T-beams) cannot again be stressed, and so cannot act as flange to the main beam.

Other designers maintain that the main beams can be designed as T-beams provided distribution bars are given in the slab across the main beams of length equal to the flange developed when the main beams are designed as T-beams. A discussion on this subject would clear a heavily-contested point which is causing some disturbance in the sphere of designing here in Bombay.—F. S. D.

Answer.—I am quite sure it is proper to consider the slab as acting in conjunction with the main beams as well as with the secondary beams. It must be remembered that the stressing of the slab by the secondary beams occurs at their midspan, and therefore far away from the main beam and on a different piece of concrete altogether.

The chief argument against it is that the compression in the slab in bending —i.e. the stress produced in the slab by having to span from one secondary beam to another—is in the same direction as the compressive stress due to the main beam. The answer to this is that the main beams support the slab laterally for a considerable distance, and this stress in the slab due to its own bending does not exist to the full extent for a certain width on each side of the main beam. This width is equal to about half the distance between secondary beams.

Occasionally cracks are found in the slab along the side of main beams. These naturally make one anxious about using the slab as a compression member. But such cracks have always, in my investigations, been due to the secondary beams being designed with too small moments or too high stresses over their supports (i.e. at the main beams), and if this is avoided there is no danger in using the slab.

As regards stressing the slab twice —once by acting as " T " of main beam and once by the bending of the slab between secondary beams, this is really guarded against by the L.C.C. limitation that the width of slab acting with the beam shall not exceed twelve times the thickness of the slab.

In practical design it is generally found that the distance between secondary beams is considerably greater than twelve times the slab thickness, and that this limitation prevents the compressed band from extending so far into the slab as to reach the parts where stress in the slab due to bending is great.

I, of course, quite agree that the slab acting as part of the main beam should have reinforcement crossing it. This reinforcement should be about—

⅜-in. rods at 6-in. centres for 4-in. slab.
½-in. rods at 6-in. centres for 6-in. slab, and so on.—Oscar Faber.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	"	14	0
" " ½ in. mesh	"	15	0
Best British Portland Cement	per ton 58s. to	63	0
"Ferrocrete" Portland Cement	10s. per ton extra		

BOARDING FOR SHUTTERING—		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	"	29	6	33	6
1½ in.	"	35	6	41	0

SAWN TIMBER FOR STRUTS AND SUPPORTS—

3 in. by 4 in. . . . . . from £24 per standard

3 in. by 6 in. and 3 in. by 7 in. . . . . " £25 " "

MILD STEEL RODS FOR REINFORCEMENT—		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
7/16 in. to ½ in. Rounds	"	13	6
⅜ in. Rounds	"	14	6
¼ in. Rounds	"	15	6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

PORTLAND CEMENT CONCRETE WELL MIXED WITH CLEAN WATER IN PROPORTION 1 : 2 : 4—		s.	d.
Do. do. in foundation	per yard cube	45	0
Do. do. in columns	" "	50	0
Do. do. in beams.	" "	50	0
Do. do. in floor slabs 4 in. thick	per yard super	5	3
Do. do. in floor slabs 6 in. thick	" "	7	9
Do. do. in floor slabs 9 in. thick	" "	11	3
Do. do. in walls 6 in. thick	" "	8	0

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

STEEL REINFORCEMENT, INCLUDING CUTTING, BENDING AND PUTTING INTO POSITION AND SECURING WITH STOUT BINDING WIRE—		s.	d.
From ¼ in. to ⅜ in.	per cwt.	23	6
" 7/16 in. to ½ in.	"	22	6
" ⅝ in. to 2⅞ in.	"	21	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.*

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.*

SHUTTERING—		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	54	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	50	0
Do. do. in small quantities	per ft. super	0	9
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	10
Do. do. as last, in narrow widths.	" "	1	0
Do. do. to sides and soffits of beams average 9 in. by 12 in.	" "	1	0
Do. do. as last, in narrow widths.	" "	1	2
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	" "	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are those current in the London area, namely:—Carpenters and joiners, 1/7½ per hour; Labourers on building works, 1/2¾; Operators on concrete mixers and hoists, 1/3¾.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

THE USE OF CONCRETE IN CHEMICAL ENGINEERING.

THE uses of concrete in chemical engineering are many and varied. It is employed for tanks for storing water, oils, solvents, alkalies, acids, wine, soap, liquors, brines, etc., settling tanks, sumps for effluents, bins for the storage of many kinds of solid materials, and it has also been used successfully in agitators in pulp mills, bleaching processes, baking ovens, condensers and coolers, gas-scrubbing towers, gas generators, leaching vats for dye, tanning pits, yeast plants, etc., and generally for walls, floors, and ordinary building work in the chemical industries. In most cases the surface of the concrete must be protected from corrosion by the application of a suitable coating, as unprotected concrete is not always suitable in chemical engineering.

Those interested in these varied uses will find much information of value in a book * which has been recently published, which also deals with the resistance of many other materials to various acids and other corrosive substances.

Confining our attention to those parts of the volume which deal specially with concrete, we find that, whilst ordinary concrete is unsuitable for many purposes, yet it can be treated in various ways to enable it to be used for corrosive substances with complete satisfaction. As the nature of the corrosive substance varies, no single method of treating the concrete is equally suitable in all cases, and for this reason the publication of a volume in which these various conditions are considered is very welcome. Thus, the success of concrete in the construction of tanks for oils depends largely on the correct selection and mixing of the materials, the proper proportion of water being of very great importance.

The action of various chemical agents on concrete is fully described, and suggestions are made as to the best methods of preventing corrosion. The section on protective coatings is particularly detailed, and occupies ten pages. There is an additional half page on the action of brine and sea water, though this section is disappointing in not suggesting any really satisfactory remedy. The application of a film of sprayed metal is suggested, but this is scarcely practicable over large areas such as sea-walls.

Those who use concrete for any purpose for which some form of protection against chemical corrosion is necessary would do well to study this volume.

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* *The Chemical Resistance of Engineering Materials.* By M. L. Hamlin, and F. M. Turner, jr. New York: Chemical Catalog Co.; pp. 226, 20 illus.)

PROSPECTIVE NEW CONCRETE WORK.

BARMOUTH.—*Defence Work.*—The M.H. has held an inquiry into an application by the U.D.C. for sanction to borrow £5,000 for sea defence works.

BECONTREE.—*Houses.*—The L.C.C. has voted another £500,000 for further development of the Becontree housing estate.

BERWICK.—*Bridge.*—The Northumberland C.C. has agreed to the erection of a new bridge over the river Tweed between the Royal Border bridge and Berwick bridge.

BILSTON.—*Sewage Works.*—The M.H. has held an inquiry into the application of the U.D.C. for sanction to borrow £9,700 for improvements at the Lunt sewage disposal works.

BLAENAVON.—*Reservoir.*—The M.H. has held an inquiry into an application by the U.D.C. for sanction to borrow £6,000 for concreting one of the reservoirs to prevent leakage.

BLACKBURN.—*Road.*—The Corporation is to consider a scheme for the construction of a new arterial road, estimated to cost £106,000.

BOSCOMBE.—*Pierhead.*—The Bournemouth Corporation is to apply to the M.H. for sanction to borrow £20,000 for the construction of a new pierhead and shelters at Boscombe.

BURY.—*Houses.*—The Corporation is to apply to the M.H. for sanction to borrow £100,000 for a housing scheme.

CARLISLE.—*Concrete Bungalows.*—The City Council proposes to erect 50 concrete bungalows.

CHORLEY.—*Sewage Works.*—Subject to certain provisions the T.C. has approved the scheme for extensions and alterations at the main sewage works, estimated to cost £50,000.

Colchester.—*Houses.*—The M.H. has approved of a scheme for the construction of 200 houses.

Colchester.—*Road.*—The B.C. has under consideration the construction of a new by-pass road, estimated to cost £75,000.

Crosby.—*Sewage Works.*—The R.D.C. has applied to the M.H. for sanction to borrow £2,050 in connection with the sewerage and sewage disposal works at Crosby.

Didcot.—*Sewage Works.*—The Wallingford R.D.C. has applied to the M.H. for sanction to borrow £3,646 in connection with sewerage and sewage disposal works at Didcot.

Disley.—*Sewage Works.*—The R.D.C. has applied to the M.H. for sanction to borrow £9,250 for sewerage and sewage disposal works at Disley.

Garlinge.—*Houses.*—The Margate T.C. proposes to construct 50 houses in the Garlinge district.

Golcar.—*Houses.*—The U.D.C. will apply to the M.H for sanction to borrow £12,609 in connection with the scheme for building 30 houses at Bull Close.

Golcar.—*Road.*—The U.D.C. proposes to construct a new road from the top of Royd Street to Townend, estimated to cost £15,000.

Grimsby.—*Sewage Works.*—The M.H. has held an inquiry into an application by the T.C. for sanction to borrow £31,000 for sewage disposal works.

Hartlepool.—*Promenade.*—The T.C. has decided to proceed as soon as possible with the extension of the North Promenade estimated to cost £40,100.

Hendon.—*Sewage Works.*—The M.H. has held an inquiry into an application by the U.D.C. for sanction to borrow £60,036 for sewage disposal works.

Hexham.—*Houses.*—The M.H. has approved of a scheme for the erection of 50 houses.

Lanchester.—*Houses.*—The M.H. has sanctioned the erection of 100 houses by the R.D.C.

Linton.—*Sewage Works.*—The Repton R.D.C. has applied to the M.H. for sanction to borrow £2,935 for sewerage and sewage disposal works at Linton.

Liverpool.—*Road.*—It is stated that £1,533,000 has been provisionally set aside as a contribution to the cost of the proposed Liverpool-Manchester road.

London (Bermondsey).—*Houses.*—The B.C. has decided to demolish 151 dwellings in the slum area near Salisbury Street, and to erect 52 houses on the cleared site. The total cost of the whole scheme is £71,050.

Lowestoft.—*Groyne.*—Subject to the approval of the Board of Trade, a concrete slab groyne of a length of 250 ft. will be placed on the South Beach.

Ludlow.—*Road.*—The T.C. proposes to construct a new road from Bromfield Road to Corve Street, estimated to cost £11,653.

Maesycwert. — *Bridge.* — The Port Talbot T.C. proposes to construct a new bridge at Maesycwert.

Margate—*Sea Wall.*—The Corporation has approved a scheme for the construction of a new sea wall and undercliff promenade, estimated to cost £36,000.

Melton Constable.—*Houses.*—The Walsingham R.D.C. proposes to build 20 houses at Melton Mowbray.

Middlesex.—*Road Works.*—The C.C. has agreed to continue the construction of the Western Avenue from Willesden Lane, Acton, to Uxbridge, the North circular road between Regent's Park Road and Green Lanes, Southgate; and the Sudbury Spur, between Harrow Road to Ealing Road. The cost, which will be borne equally by the Council and the M.T., is estimated at about £1,000,000.

Newton Heath.—*Houses.*—The Manchester Corporation Housing Committee has received sanction to borrow £312,568 for the erection of houses on the Burnage and Newton Heath estates.

Norwich.—*Houses.*—The T.C., has a scheme on hand for the erection of 1,000 houses.

Peterborough.—*Houses.*—The T.C. proposes to erect 16 houses in Grange Road, both in brick and concrete.

Portsmouth.—*Sea Wall.*—The T.C. will apply to the Government for sanction to borrow £6,000 for constructing a concrete sea-retaining wall.

Rhigos.—*Road.*—The Rhondda U.D.C. proposes to construct an arterial road from Rhigos to Treherbert, estimated to cost £30,000.

Rothesay.—*Sewage Works.*—The T.C. has agreed to proceed with a sewage disposal scheme, estimated to cost £40,000.

Solihull. — *Defence Works.* — The U.D.C. has applied to the M.H. for sanction to borrow £5,000 for sea defence works and promenade improvements.

SOUTHGATE. — *Open-Air-Bath.* — The U.D.C. proposes to construct an open-air swimming bath, estimated to cost £3,750.

SWANSEA.—*Houses.*—The Corporation has sanctioned a scheme for the erection of 250 houses in concrete.

SWINTON.—*Houses.*—The U.D.C. has received sanction from the M.H. to erect 50 houses.

WAKEFIELD.—*Reservoirs.*—The Corporation will apply for powers to acquire water rights, and to construct reservoirs in the Rushworth area.

WELLINGTON.—*Houses.*—The U.D.C. has decided to erect 30 houses on the Council's land off Worthing Street.

WELSHPOOL.—*Reservoirs.*—The T.C. will forward to the M.H. proposals for improvements to the town reservoirs.

WEST MERSEA.—*Sewage Works.*—The Lexden and Winstree R.D.C. has received sanction to a loan of £11,000 for the West Mersea sewage scheme.

WORCESTER. — *Sewage Works.* — The M.H. has held an inquiry into an application by the T.C. for sanction to borrow £10,765 for sewage disposal works.

WREXHAM.—*Houses.*—The R.D.C. has applied to the M.H. for sanction to build 200 houses.

TENDERS ACCEPTED.

AMERSHAM. — *Sewage Works.* — The R.D.C. has accepted the tender of Messrs. Edgar and Mole, Newbiggin-by-Sea, at £2,222 10*s.* 6*d.*, for the construction of the sewage works at Chesham Bois.

CHELTENHAM.—*Paving.*—The T.C. has accepted the tender of the Atlas Stone Co., for the supply of concrete flagging at 5*s.* 6*d.* per yard super.

DUMFRIES.—*Cooling Tower.*—The T.C. has accepted the tender of Messrs. Premier Cooling and Engineering Co., Ltd., at £386, for the construction of a reinforced concrete cooling tower.

ENFIELD.—*Sewage Works.*—The U.D.C. has accepted the tender of Messrs. W. & C. French, Buckhurst Hill, for the construction of sewage disposal works at Cuckoo Hall Lane, Lower Edmonton.

FLIXTON.—*Street Improvement Works.* —The Barton-upon-Irwell R.D.C. has accepted the tender of Messrs. A. Monk & Co., Irlam, at £5,569 11*s.*, for kerbing, channelling, flagging, and paving in concrete.

KEIGHLEY. — *Concrete Pipes.* — The R.D.C. has accepted the tender of T. Moore, Esq., Keighley, at £229, for the laying of concrete pipe drain in Banks Lane.

LINTHWAITE. — *Houses.* — The U.D.C. has accepted the tender of Messrs. J. Winpenny & Co., Linthwaite, at £3,965 4*s.* 4*d.*, for the erection of 10 concrete houses.

LONDON (BATTERSEA).—*Foundations.* —The L.C.C. has accepted the tender of Messrs. W. Akers & Co., Ltd., at £2,196, for work in connection with foundations for rebuilding Raywood Street School.

LONDON (GREENWICH).—*Coal Bunkers, etc.*—The L.C.C. has recommended for acceptance the tender of Messrs. Industrial Constructions, Ltd., Grosvenor Place, S.W.1, at £34,876, for the construction of coal bunkers, etc., at the Greenwich power station.

LONDON (LEWISHAM). — *Tubes.*—The B.C. has accepted the tender of Messrs. J. Ellis & Sons, Ltd., for the supply of 3 ft. by 2 ft. concrete tubes required in connection with the reconstruction of Wells Road sewer.

LONDON (TOOTING).—*Foundations, etc.* —The L.C.C. has recommended for acceptance the tender of Messrs. Douglas Halse & Co., Ltd., Woolwich, at £5,061, for work in connection with foundations, etc., of new secondary school on the Beechcroft Road site.

MANCHESTER.—*Paving.*—The Corporation has recommended for acceptance the tender of Messrs. Brookes, Ltd., Halifax, for the supply of concrete flags.

POOLE.—*Sea Wall.*—The T.C. has accepted the tender of Mr. T. Wilkinson, at £3,919, for the construction of a sea wall at the Sandbanks recreation ground.

SEATON, DEVON.—*Sea Wall.*—The U.D.C. has accepted the tender of Messrs. F. Bevis, Ltd., Portsmouth, at £4,167 15*s.*, for the construction of approximately 400 lineal yards of reinforced concrete sea wall.

WITHAM (ESSEX).—*Sewage Disposal Works.*—The U.D.C. has accepted the tender of Messrs. W. & C. French, Buckhurst Hill, at £7,640, for the construction of sewage disposal works.

The Schwager Building, Valparaiso.

"B.R.C." Fabric was used to reinforce the floors of the Schwager Building, Valparaiso, illustrated in our last issue.

Single Copies, 1s. 6d. nett. *Annual, Post Free, 18s.*

CONCRETE AND CONSTRUCTIONAL ENGINEERING

FEBRUARY 1924 VOL. XIX. No. 2

A MONTHLY JOURNAL for Engineers, Architects, Surveyors and Contractors and all interested in Cement, Concrete, Reinforced Concrete, Fire-Resisting Construction and Structural Steel.

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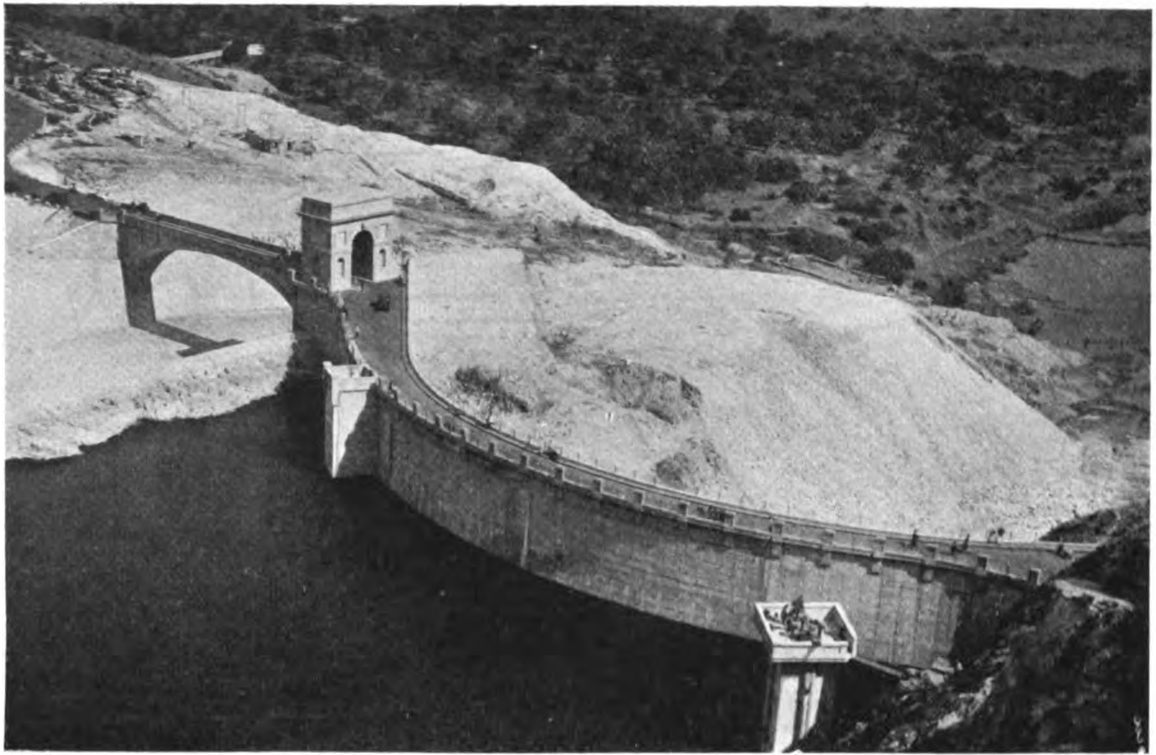


HARTEBEESTPOORT DAM, FROM RIGHT BANK.
(*See p.* 87.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIX. No. 2. LONDON, FEBRUARY, 1924.

EDITORIAL NOTES.

REINFORCED CONCRETE CONSTRUCTION.

In his Presidential Address delivered to the Sheffield Section of the Junior Institute of Engineers, " Recent Progress in Engineering," Professor Husband said many things about reinforced concrete which must have left in the minds of his audience the impression that reinforced concrete as a structural material cannot live up to the claims that are made for it.

Professor Husband, as a professor in a British University and as a writer on structural engineering, holds such a position that any opinions expressed by him must be treated seriously, and we do not imagine that he intended his words to be used as more than a warning that we must not regard reinforced concrete as a new magical material which will be the best for all structures and will ultimately drive all others out of existence. With this warning we are in cordial agreement, and have often stated that people do a disservice to reinforced concrete who make obviously extravagant claims as to its advantages.

Some of the statements made about reinforced concrete in this address, however, in our opinion go much too far. In the copy before us we read: " It is notorious that the majority of those who use it, or are responsible for ordering its adoption, often have a very elementary knowledge of its theory." We doubt very much whether this is true, but if it is, exactly the same statement could be made concerning structural steelwork, and in any case it is surely not the fault of reinforced concrete if its theory is not more fully understood by the people who use it.

We read next: " After thirty years of investigation it is still necessary to make a 100 per cent. allowance in designing members subject to bending, in order to cover uncertainty of distribution of stress, and it is doubtful if this disability will ever be removed." We cannot understand Professor Husband's meaning here; probably most of his audience gathered that reinforced concrete beams should be designed for a factor of safety at least twice as great as that used in steel beams, but this is certainly not the case. In the usual practice in reinforced concrete design a so-called factor of safety of 4 is taken; this means we assume that the stress in the steel will be 16,000 lbs. per sq. in. (one-fourth of its ultimate strength) and the stress in the concrete will be 600 lbs. per sq. in. (one-fourth of its ultimate strength); thousands of tests have proved that a beam so designed will require at least four times its design load to cause failure. Very little information is published upon the test strength of ordinary steel beams, but the factor of safety on test under the same conditions is often nearer three than four.

In speaking in rather pessimistic terms of the indestructibility and fire-resistance of reinforced concrete Professor Husband says: "No one has yet succeeded in making concrete impervious to air and water." . . . "Concrete is an artificial stone, and the best man-made concrete is still inferior in homogeneity and impermeability to the denser varieties of nature-made stone, whilst the average concrete in common use is more inferior still." The first is an amazing statement; concrete tanks have been made which are impervious to petrol, which is far more penetrating than water. The second statement does not take one very far if it be correct or not, because the comparison is unfair; the real question is whether the average concrete is inferior to the average stone.

Professor Husband later states that "Generally it may be conceded that reinforced concrete is eminently suitable for structures of a temporary or semi-temporary character, out of contact with water, and of relatively simple and rectangular design, involving economical moulding forms." This at least is something, and we are to be allowed to continue an existence for structures of a temporary or semi-temporary character! What materials we are to use for permanent structures we know not, because a little later on Professor Husband gives the probable life of a reinforced concrete structure as 80 to 100 years, whereas that of a well-designed steel structure, reasonably well cared for, should extend to 60 years.

CONCRETE PRODUCTS.

FROM small beginnings, when practically the only small articles made from concrete were partition slabs and garden rollers, the manufacture of concrete products has developed into a large industry employing a large amount of capital and labour. Nowadays partition slabs and rollers form but a minor part of the activities of an industry whose manufactures vary from fixing bricks to telegraph posts and all kinds of cast-stone ornamental details for buildings, and often entire façades of important buildings in cast stone. Concurrently with this development in the range of goods known under the generic name of "concrete products" it is gratifying to note a very marked improvement in the quality and design of the articles manufactured. Haphazard methods are rapidly disappearing, and a scientific knowledge of the properties of concrete and the processes of its manufacture are brought to bear in the production of the excellent articles which are now being used for a variety of purposes too numerous to mention. For many purposes concrete is the obvious material to use, both from the points of view of suitability and cost, but there are many other uses for which the material can be advantageously adopted. The obvious uses are generally those where strength is the chief requisite, but the very fine results which may be obtained through a thorough knowledge of the material and of modern methods of obtaining clean, sharp, and coloured surfaces open up an almost unlimited future for what is generally known as artificial stone—or cast stone, as we prefer to call it. How many people who admire stone-fronted buildings in our big towns realise that they are often not looking at natural stone at all, but at cast-stone? Yet it is a fact that pre-cast concrete, made with a fine aggregate, has been used for a very large proportion of the " stone " fronts of the new office buildings recently erected and in course of erection in London. The difference between natural stone and moulded stone is unnoticeable without a close inspection and can rarely be discovered at all after they have weathered for a few years. Moreover, the building suffers no loss in dignity because exactly the same features which were in the past laboriously cut from quarried stone are made in a mould from materials also obtained from the earth's surface, and at a considerably less cost.

In view of the importance of this industry we commence this month a section devoted to concrete products, which will be a regular feature in future issues. In these pages we hope to give useful articles and hints on the manufacture and uses of concrete products, and to illustrate and describe new applications of the material. Such a section will, we feel sure, be of considerable value to all concerned with this branch of the concrete industry by forming a link between the manufacturers of pre-cast concrete goods, who have hitherto had no definite representation in the technical press, and that section of the public more particularly interested in the use of concrete products.

CONCRETE AND THE SUPPLY OF SKILLED LABOUR.

It is difficult to understand the philosophy of a body of men apparently anxious to destroy their means of livelihood ; and yet the action of certain of the building trade operatives in refusing to admit into their ranks sufficient men to do the work waiting to be done is certainly resulting in less work for those already in those trades. A week or two ago it was stated in the Press that there had been no bricklayers on the books of the Employment Exchange in a large south-coast town for two years, and that building operations were being held up in consequence. The report of the Edinburgh Director of Housing, given elsewhere in this issue, is an illuminating commentary on the results of the anti-dilution attitude, and it is certain that others responsible for large building schemes will also get over the difficulty of obtaining bricklayers by the simple method of building in materials which do not require their services. Such an effect was no doubt far from the minds of the trade unions when they formulated their policy, but surely they could not expect that a comparatively small body of men could withhold urgently-required buildings from the rest of the population ? In the search for a solution of the problem created by a shortage of bricklayers the fact that unskilled workers can be easily trained to carry out concrete work under proper supervision—with equally good results and at no more, or less, cost—is being more generally realised.

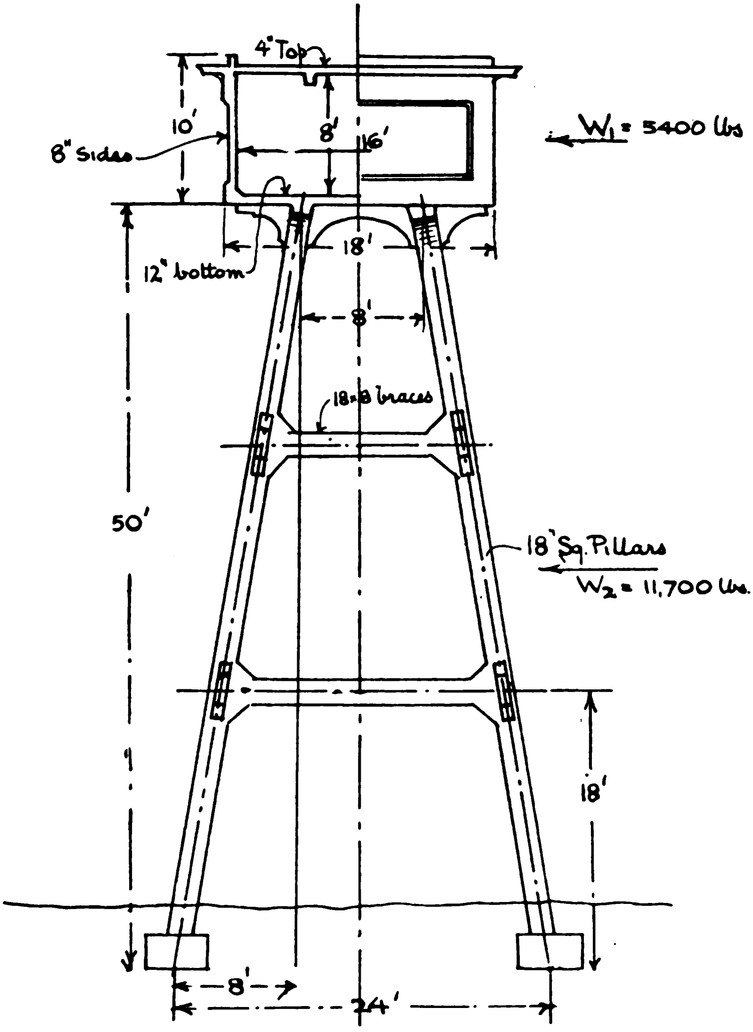


Fig. 1. Diagram of Water Tower

O.F.
24-1-24.

SIMPLE EXAMPLES OF REINFORCED CONCRETE DESIGN. (*See p. 71.*)

SIMPLE EXAMPLES OF REINFORCED CONCRETE DESIGN

(*Continued from January*, 1924.)

By OSCAR FABER, O.B.E., D.Sc.

EXAMPLE No. 6—WATER TOWER.

We will take as our example the water-tower illustrated in *Fig.* 1.

The main dimensions are 16 ft. by 16 ft. by 8 ft. inside the reservoir, and the bottom is 50 ft. above the foundations.

Allowing for 7 ft. depth of water, the capacity would be

16 ft. by 16 ft. by 7 ft. =	1,800 cu. ft.
or	11,200 galls.
which weighs	112,000 lbs.

After what has already been said in the previous examples, and particularly in Example No. 2, it will be assumed, for the sake of avoiding repetition, that the student can design the tank portion.

We will assume that the main dimensions resulting from such design are as follows :—

Roof	4 in. thick
Walls	8 in. ,,
Bottom	12 in. ,,

The weight of the tank may then be determined as follows :—

Roof and cornice	24 ft. by 24 ft. by 50 lbs. =	28,800 lbs.
Bottom	18 ft. by 18 ft. by 150 lbs. =	48,600 ,,
Sides and curb	4 × 17 ft. by 9 ft. by 100 lbs. —	61,200 ,,
Beams and projections say	=	10,000 ,,
		148,600 ,,
	say,	150,000 ,,

The weight of the tower, assuming the columns or pillars to be 18 in. square and the braces 18 in. by 8 in., will be

4 pillars	4 × 50 ft. × 2¼ × 150 =	67,500 lbs.
Upper braces	4 × 12 ft. × 150 =	7,200 ,,
Lower braces	4 × 17 ft. × 150 =	10,200 ,,
		84,900 ,,
	say,	85,000 ,,

The total load is therefore

Water	112,000 lbs.
Tank	150,000 ,,
Tower	85,000 ,,
	347,000 ,,

Hence the load per pillar (with no wind) is

$$\frac{347{,}000}{4} = 86{,}750 \text{ lbs.}$$

Taking our standard 18 in. by 18 in. pillar (see "Reinforced Concrete Simply Explained," p. 53) it will be seen that the standard reinforcement is 8 ¾-in. rods, the equivalent area is 373 sq. in., and hence the stress is $\frac{86{,}750}{373} = 233$ lbs./ins.^{2}

It may be thought that this is rather low, but we will show that the action of wind is to increase this considerably.

In the above calculation, no correction has been made for the obliquity of the

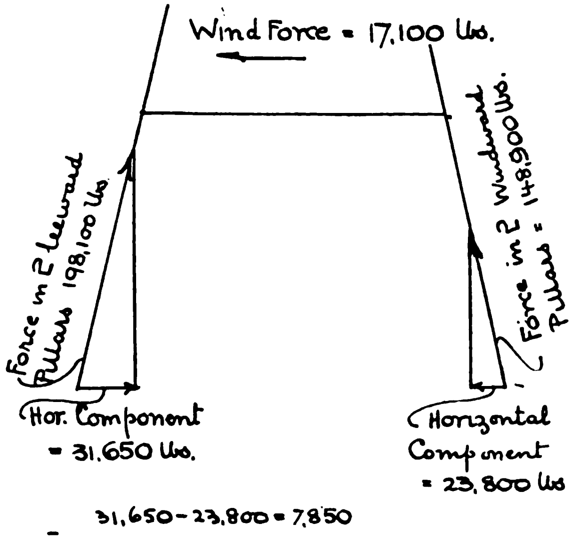

Wind Force = 17,100 lbs.
Force in 2 Leeward Pillars 198,100 lbs.
Force in 2 Windward Pillars = 148,900 lbs.
Hor. Component = 31,650 lbs.
Horizontal Component = 23,800 lbs
31,650 - 23,800 = 7,850
=

Fig. 2

Diagram of Forces in Pillars

O.F. 24-1-24.

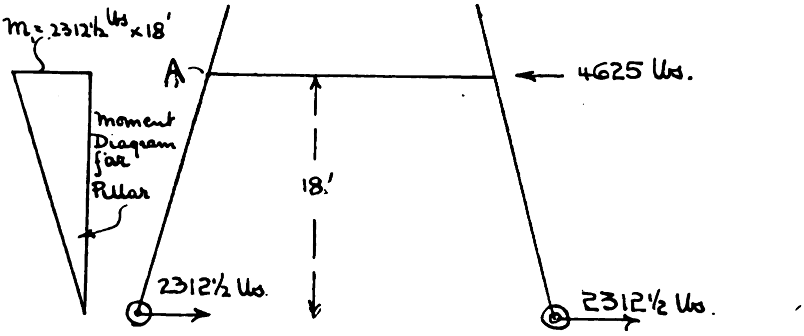


Fig. 3.

Forces on each pillar producing moments (or Racking)—Pillars with hinged ends.

O.F. 24-1-24.

pillars. Strictly speaking, the above stress should be increased in the ratio of the oblique length of the pillar to its vertical height. For small obliquities, as in the present case, this effect is negligible.

The effect of wind is chiefly two-fold :

(1) To move the resultant thrust on the ground from the centre of the tower towards the leeward pillars, increasing the load on these and reducing the load on the windward ones.

(2) To produce a racking effect on the tower, which is resisted by the stiffness of the joints, and produces moments in the pillars and braces.

The splayed form of tower as illustrated in this example is very helpful by reducing the stresses from both these causes.

We will first calculate the wind pressures as follows, taking the unit pressure as 30 lbs. a sq. ft. of exposed surface.

$$W_1 = \text{Wind pressure on tank}$$
$$= 18 \text{ ft. by } 10 \text{ ft.} \times 30 \text{ lbs.} = 5{,}400 \text{ lbs.}$$

Its moment about the base is

$$M_1 = 5{,}400 \times 55 \text{ ft.} = 297{,}000 \text{ ft. lbs.}$$

The area of tower (two pillars and two braces) in elevation is

$$2 \times 50 \times 1\tfrac{1}{2} + 30 \times 1\tfrac{1}{2} = 150 + 45 = 195 \text{ sq. ft.}$$

Actually, however, the wind will exert nearly the same pressure on the back pillars and braces as the shielding effect of the front ones is negligible.

Hence

$$W_2 = \text{Wind pressure on tower}$$
$$= 2 \times 195 \times 30 = 11{,}700 \text{ lbs.}$$

Its moment about the base is

$$M_2 = 11{,}700 \times 25 \text{ ft.} = 292{,}000 \text{ ft. lbs.}$$

Hence the total wind moment about the base is $M_1 + M_2 = 589{,}000$ ft. lbs.

This produces an additional pressure on the two leeward pillars of

$$\frac{589{,}000}{24} = 24{,}600 \text{ lbs.}$$

or 12,300 lbs. on each of them, and of course, reduces the load on the two windward pillars by an equal amount.

Hence the corrected direct stress in the leeward pillars after allowing for wind effect No. 1 is

$$\frac{86{,}750 + 12{,}300}{373} = \frac{99{,}050}{373} = 265 \text{ lbs./ins.}^2$$

Coming now to the effect of racking due to the wind, this is not quite so simple, but it is hoped that the following puts it as clearly as is possible in a small space.

Let us consider the lowest panel, i.e., under the lowest brace. This is clearly where the effect is most marked. The total horizontal wind force across this panel is clearly

$$W_1 + W_2 = 17{,}100 \text{ lbs.}$$

If the pillars were vertical, the whole of this would produce racking. But the pillars, being inclined as drawn, the loads in them have horizontal components. The horizontal component of the two leeward pillars is

$$2(86{,}750 + 12{,}300) \times \frac{8'}{50'}, \text{ against the wind,}$$

and that of the two windward pillars is

$$2(86{,}750 - 12{,}300) \times \frac{8'}{50'}, \text{ with the wind.}$$

It will be seen that the nett effect is to produce a total horizontal force of

$$4 \times 12{,}300 \times \frac{8'}{50'} = 7{,}850 \text{ lbs.}$$

against the wind.

In other words, the wind force producing racking across the panel is reduced from 17,100 lbs. to 17,100 − 7,850 = 9,250 lbs.

This is a very valuable reduction and well illustrates the importance of inclined supports in structures of this kind, which was taken full advantage of in the Eiffel Tower.

This effect of the inclined pillars assisting in resisting wind is further illustrated in *Fig.* 2. It will be seen that the nett force helping to resist wind is

$$31{,}650 - 23{,}800 = 7{,}850 \text{ lbs.}$$

as before. The remainder of the wind force, 9,250 lbs., which is not taken up by the difference in the horizontal components in the pillar thrusts, clearly produces bending in the pillars.

This is, perhaps, made clearer in *Fig.* 3, where the force is shown as shared equally by the four pillars. If the bases are considered as hinged or rolling, then clearly these forces would produce a moment of 2,312½ × 18 = 41,600 ft. lbs. at the point A in the pillar.

If, however, as more generally is the case in good design, the base is made large enough so that it may be considered fixed in direction, then the moment may be considered as distributed as shown in *Fig.* 4 and to have half the previous value, namely,

$$M = 20{,}800 \text{ ft. lbs.}$$
$$= 249{,}600 \text{ in. lbs.}$$

As the moment of inertia of our standard 18 in. by 18 in. pillar is 10,510 inch units (see " R.C.S.E." p. 53) the stress in it due to this moment would be

$$\frac{Md}{2I} = \frac{249{,}600 \times 18 \text{ in.}}{2 \times 10{,}510}$$
$$= 214 \text{ lbs./ins.}^{2}$$

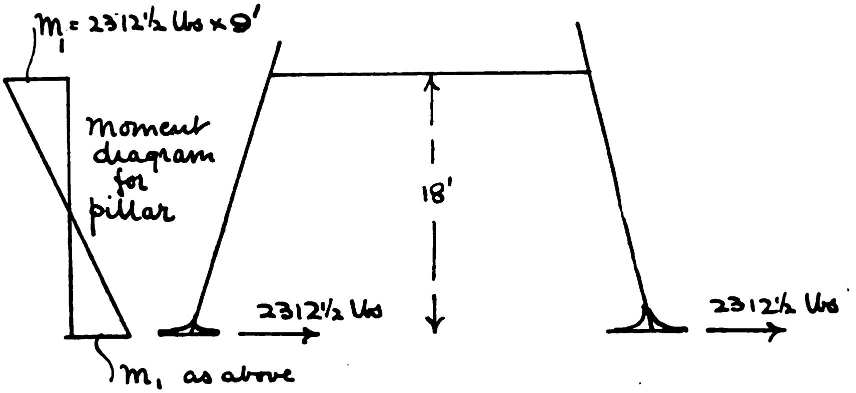


Fig. 4.

Forces on Each Pillar producing moments. (or Racking)
Pillars with Fixed Ends. O.F. 24-1-24.

Hence the maximum stress in the pillars is :

direct	265	lbs./ins.^{2}
bending or racking	214	,,
Total	479	,,

If we now consider the pillars in the panel above, we shall obtain very similar results, so that the moment diagram in the pillars is as indicated in *Fig.* 5. It will be clear that the end of the brace has to resist (because there is nothing else to do so) the moment M_1 from the pillar below plus the nearly equal moment M_2 from the pillar above. So that the moment in the brace will be roughly

$$M_1 + M_2 = 2M_1 \text{ approx.} = 499{,}200 \text{ in. lbs. (approx.)}$$

at the ends, and varying along it as drawn.

This result can be obtained another way as a check. The effect of wind, as already stated, has been to add 12,300 lbs. on to each of the two leeward pillars. This may be considered as added in three approximately equal instalments at each of the panel points, namely, 4,333 lbs. at each. The moment required at the fixed end

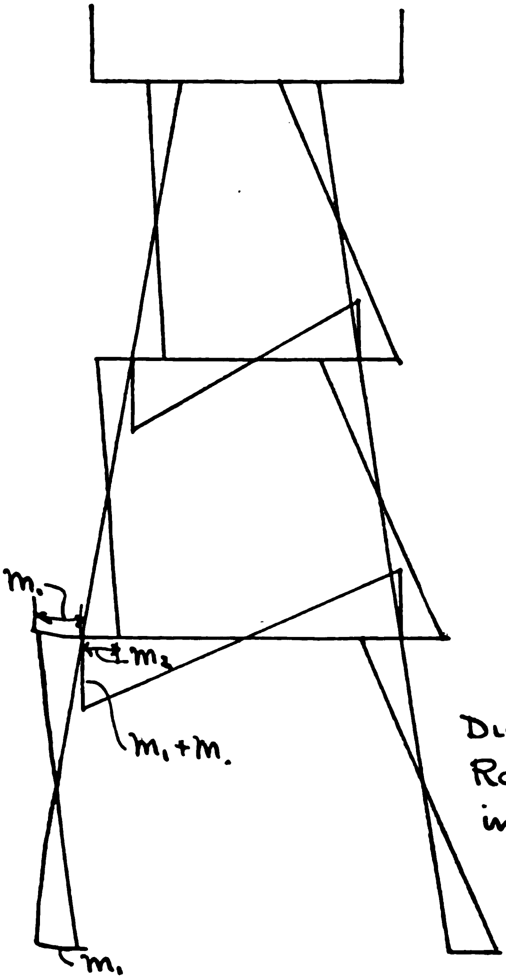


Fig. 5.
Diagram of
Racking Moments
in Pillars and
Braces.
O.F.
24-1-24.

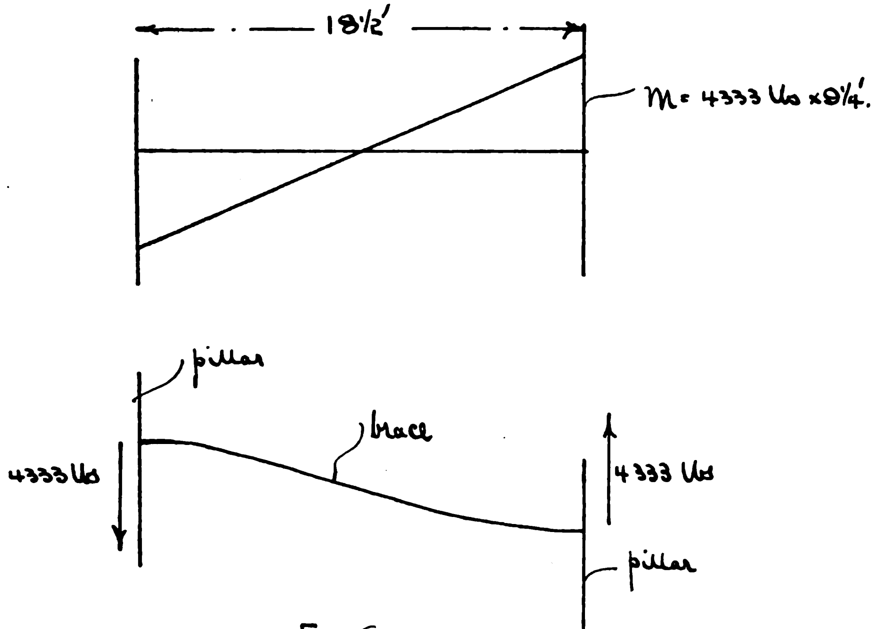


Fig. 6.
Moment Diagram
and Racking Effect
on Brace

O.F.
24-1-24.

of a brace 18½ ft. long, to carry this load at the other end (being free) would clearly be

$$
\begin{aligned}
& 18\tfrac{1}{2} \text{ ft.} \times 4333 \text{ lbs.} \\
= \; & 80{,}000 \text{ ft. lbs.} \\
= \; & 960{,}000 \text{ in lbs.}
\end{aligned}
$$

If both ends are equally fixed, this moment is shared betweeen them, giving a moment of 480,000 in. lbs. at each end. This agrees with sufficient accuracy with the previous result.

A diagram illustrating this method of treating the braces is given in *Fig.* 6.

If we make the braces 18 in. by 8 in., the steel required at the end would be about

$$\frac{480{,}000}{14'' \times 16{,}000} = 2{\cdot}15 \text{ ins.}^2$$

say, 2 1⅛-in. rods top and bottom.

In addition, haunches and haunch bars are desirable at the ends, so as to provide adequate adhesion.

A HANDBOOK AND DIRECTORY FOR THE CONCRETE INDUSTRY.

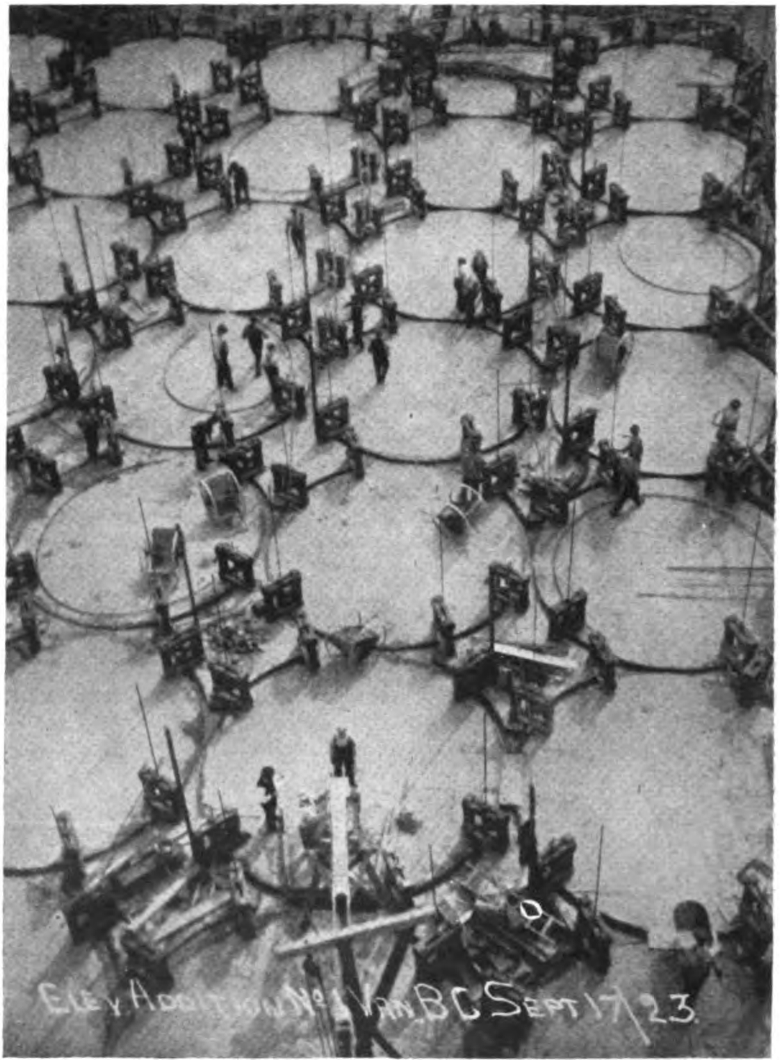
As we anticipated, there has been a very great demand for the first edition of "The Concrete Year Book," and we would advise those of our readers who wish to have a copy to make early application by filling in the order form on page xxiii. The obvious need for such a work has been commented on by several reviewers in the technical press, and it is gratifying to note that it has been well received generally. "Engineering," for instance, states: "There must be many to whom such a volume will be useful. . . . The book now before us makes an excellent start, and covers useful ground;" "The Builder" says: "By following the rules and principles given anyone will be able to make a good concrete at no more cost than a poor one;" the "Manchester Guardian" says: "This is a new venture to serve an industry which has hitherto had no such work specially prepared for it. . . . The editors may be congratulated on having made an excellent beginning;" and many other favourable reviews have appeared in authoritative journals.

"The Concrete Handbook, 1924," is edited by Dr. Oscar Faber, O.B.E., D.Sc., and the Editor of Concrete Publications, Limited, and is divided into three distinct parts, namely (1) a Handbook in which is given much useful information on the practical applications of concrete, (2) a complete Directory of the concrete industry, and (3) a Catalogue of the industry. In the Handbook section the editors have endeavoured to present methods essential for the production of the best, and at the same time the cheapest, concrete in a form which should be readily understood by everyone connected with the industry, written throughout in simple language. Chapters are given on the economical use of cement, proportioning and grading aggregates to secure the best results, concreting in cold weather, memoranda for use in concrete work, standard specifications for various types of concrete floors, surface treatments, concrete roads, a series of specially prepared tables for reinforced concrete design, a complete bibliography of all books on concrete and allied subjects, and much other useful information.

The Directory Section forms a complete guide to the industry and is classified under different headings, including Consulting Engineers who Specialise in Reinforced Concrete, Reinforced Concrete Designing Firms, Public Works Contractors who Specialise in Concrete Construction, Concrete Flooring Specialists, Suppliers of Aggregates and Sand, Artificial Stone Manufacturers, Manufacturers of Colouring Materials for Concrete, Manufacturers of Machinery and Plant for Concrete and General Constructional Work, Manufacturers of Concrete Products, Manufacturers of Reinforcement, Contractors for Concrete Roads, Manufacturers of Proofers and Hardeners for Concrete, Piling Contractors, Manufacturers of Asbestos-Cement Products, Concrete Testers, etc. No pains have been spared to make the Directory Section as complete and accurate as possible, and its value is enhanced by complete lists of the products of each firm.

The third section of the publication is a Catalogue of the industry, containing within 150 pp. full descriptions of the businesses, manufactures, or products of some 120 different firms connected with the industry.

The volume, which is strongly bound, and comprises 350 pages, is published by Concrete Publications, Ltd., Publishing Department, 4 Catherine Street, Aldwych, W.C.2, price 3s. post free.



REINFORCED CONCRETE GRAIN ELEVATOR AT VANCOUVER: DURING CONSTRUCTION (September 17, 1923). (*See p.* 79.)

REINFORCED CONCRETE GRAIN SILO AT VANCOUVER.

AN EXAMPLE OF RAPID CONSTRUCTION.

Known as the No. 1 Dominion Government Grain Elevator, the reinforced concrete grain silo at Vancouver, B.C., is an example of remarkably rapid construction, the whole of the concrete having been poured in 15 days with the use of moving forms.

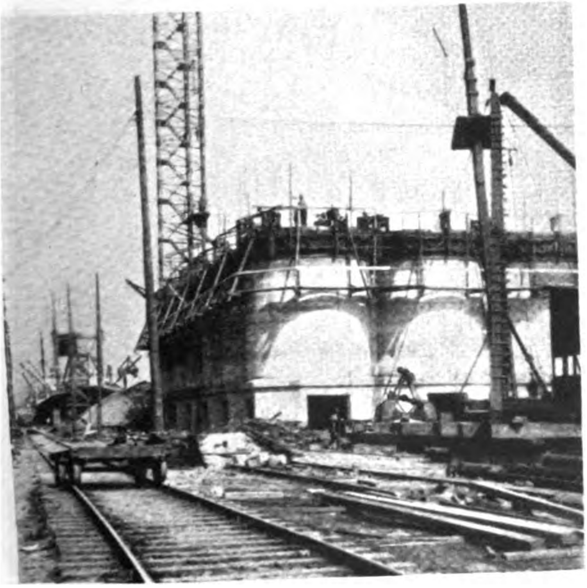
Pouring of the bin walls, which are 90 ft. high by 20 ft. in diameter, and contain 4,380 cu. yds. of concrete, was commenced by a night shift at 1 a.m. on September 6, 1923, and completed to the full height by noon on the 21st of the same month.

Work on pouring the columns and beams of the working house was carried on simultaneously with the storage house, with moving forms working in conjunction with the circular bin forms. In this portion of the work 838 cu. yds. of concrete were used, and from the point where pouring started the height is 148 ft.

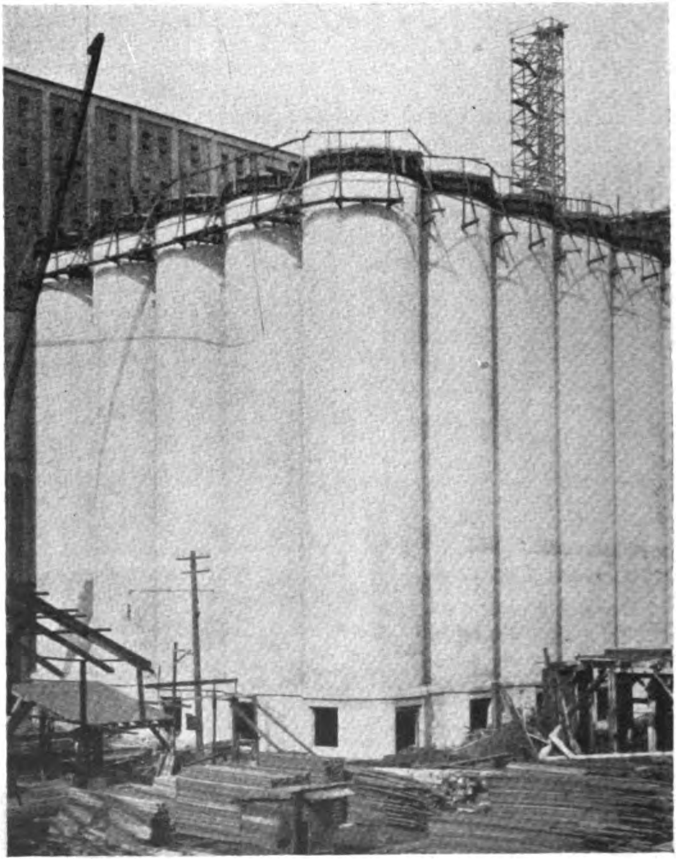
Work on the pouring of the cupola which extends beyond the top of the storage bins was commenced in the afternoon of September 26, and completed on the morning of October 5.

The storage capacity of the bins is 850,000 bushels, made up of 35 circular bins of 21,000 bushels capacity each, and 28 interspace bins of approximately 5,000 bushels each.

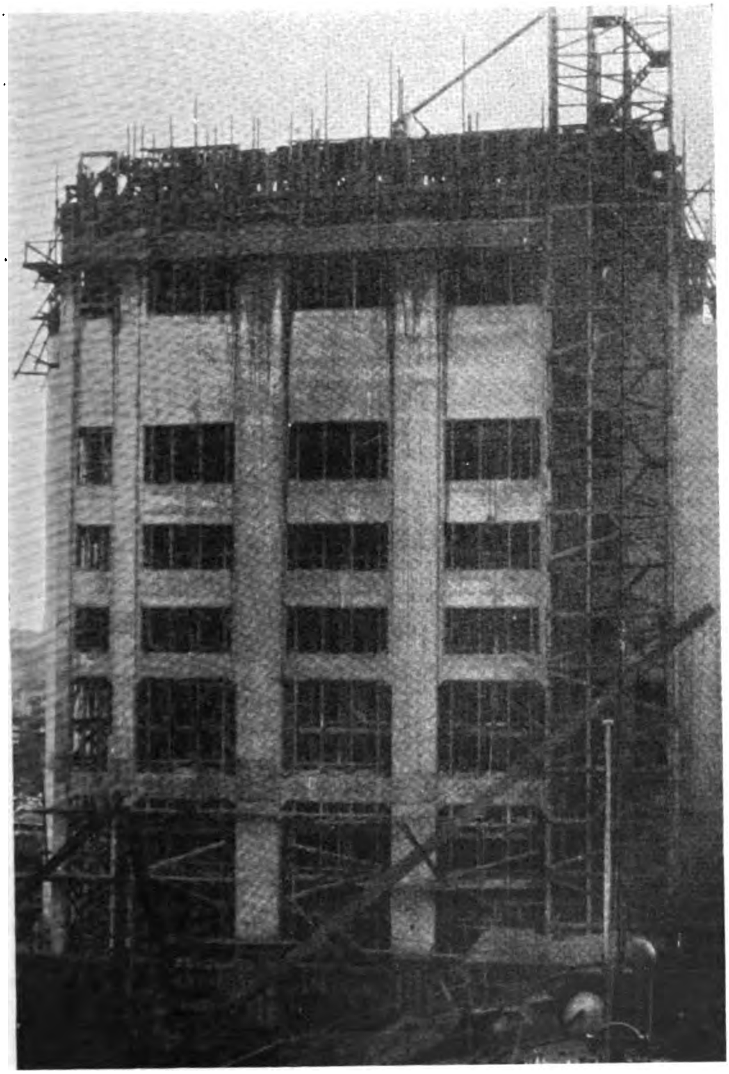
The construction was carried out by the John S. Metcalf Co., Ltd.



Reinforced Concrete Grain Elevator at Vancouver:
During Construction (September 11, 1923).



REINFORCED CONCRETE GRAIN ELEVATOR AT VANCOUVER: NEARING COMPLETION (September 24, 1923).



REINFORCED CONCRETE GRAIN ELEVATOR AT VANCOUVER:
WORKING HOUSE (September 28, 1923). (*See p.* 79.)

BOOK REVIEW.

"Sands and Crushed Rocks." By Alfred B. Searle.

Vol. 1. "Their Nature, Properties and Treatment" (475 pp., 151 illustrations); *Vol.* 2. "Their Uses in Industry" (230 + 51 pp., 12 illustrations). (London: Oxford Technical Publications. Price 52*s.* 6*d.*)

THIS is probably the first attempt to deal with the subject of sands and crushed rocks in all its various aspects, and is therefore a welcome addition to the bookshelf. Perhaps most of the information could be found in other places, but the search would be uninviting and tedious. This is perhaps inevitable, and it seems that a book which presents all the available information on any subject in a convenient and portable form is just as useful in its class as the comparatively rare book which breaks entirely new ground.

In "Sands and Crushed Rocks" the information is collected by a man who knows his subject, and the addition of personal experience enables him to make the book something more than a mere assembly of facts. The division into two volumes is a natural one, and would have been quite satisfactory but for the fact that there is only one index, this occurring at the end of the second volume. Apparently the volumes are not intended to be sold separately.

Vol. 1.—The first two chapters deal with the geological and geographical distribution of sands and rocks. The ninety pages following are devoted to a description of the chief characteristics of various sands and rocks, the list being arranged alphabetically: this is exceptionally good. The constituents, properties, and testing of sands are discussed. The question of grading is troublesome, and the methods of Jackson, Mellor, Feret, and Boswell are given at length. The section dealing with the Refractory Properties of Sands gives all the necessary facts, but their direct application to the question of fire-resistance would have made the matter of more practical value to the structural engineer. Under the heading "Porosity" the usual method of obtaining voids is given. Although this is in general use it is apt to be misleading since it is impossible to drive out all the air without disturbing the position of the sand grains, and since there is often a variable amount of water already in the sand. This is pointed out by the author, and a corrective formula is given. The question is of some importance in concrete work. Chapters are devoted to Mining and Quarrying; Crushing and Grinding; Purification; Grading; Storage, Packing, and Despatching. Much of this is of value to the reinforced concrete engineer, and a description of the machinery used forms a fitting sequel to the previous theoretical treatment.

Vol. 2.—Uses of sands and crushed rocks in various industries are given, and though some of these are of minor interest to the reinforced concrete engineer (e.g., metallurgy, refractory materials, agriculture, filtration, chemical industry, pottery manufacture, glass-making, abrasives, explosives, etc.), the first five chapters deal with bricks, artificial stones, concrete, cements, mortars, plasters, and roads. The information contained herein is good, although somewhat limited on account of the wide range of the subject. Much useful information is given on impurities, grading, etc., of aggregates for concrete. Little is said of the actual mixing, which marks the limit of the author's treatment of his subject.—J. S.-G.

"A Pre-Cast Reinforced Concrete Footbridge."

WE regret that in our last issue the name of Mr. W. H. Shortt, M.Inst.C.E., was accidentally omitted as the author of the article illustrating and describing the interesting work in connection with the pre-cast reinforced concrete footbridge recently erected at one of the stations in his District on the Southern Railway, the whole of which was carried out under Mr. Shortt's supervision as District Engineer.

CHART FOR DESIGNING BEAMS IN COMPRESSION OR TENSION.

By E. M. ROYDS-JONES, D.I.C., A.C.G.I., B.Sc.

THE accompanying chart (pp. 84–85), expressing graphically the results of calculations by the writer, will be found very useful to those who have occasion to design beams or slabs subjected to compression or tension as well as bending moment. The chart is meant to be used for concrete members whose function is essentially that of a beam and not of a column, i.e., the main reinforcement is considered to be on the tension side only.

The calculations are based on the ordinary assumptions of beam design, i.e., that plane sections remain plane, and that the concrete takes all the compression and the steel all the tension. The end thrust or tension is assumed to act through the centre of the depth of the beam. If it acts eccentrically the bending moment thus produced must be calculated and added to or subtracted from the main bending moment, according to whether the end force is towards the compression or tension side of the beam. The cover to the steelwork is taken at values commonly used in reinforced concrete design, and varies from a depth of 1 in. to the centre of the steel in a 6-in. slab to 2 in. in an 18-in. slab, as is shown in the table on the right of the chart.

One example should be sufficient to explain the chart if its use is not obvious :

EXAMPLE.

A 10-ft. width of slab must resist a bending moment of 110,000 lbs.–ft. and a compressive end thrust of 120,000 lbs. Then the bending moment per foot width of slab is 11,000 lbs.–ft., and the end compression per foot width of slab is 12,000 lbs. On the chart, follow the vertical ordinate representing 11,000 lbs.–ft. downwards until it meets the horizontal coordinate representing a compression of 12,000 lbs. per ft. width. This gives the required thickness of the slab as 15 in., and the area of main reinforcing steel as 0·33 sq. in. per ft. width of slab. The depth from the outside of the beam to the centre of the steel used in calculating the chart is found from the right-hand side to be 1¾ in.

If the end thrust, instead of acting through the centre of the depth of the slab, acted at a point 3 in. from the centre towards the compression side of the slab, then the bending moment per foot width of slab due to this eccentricity is $\frac{3}{12} \times 12{,}000 = 3{,}000$ lbs.–ft., which must be added to the existing bending moment of 11,000 lbs./ft., giving a total bending moment of 14,000 lbs.–ft. per foot width of slab. The thickness of slab required for this bending moment with end thrust of 12,000 lbs. is 16½ in. with 0·44 sq. in. of main reinforcing steel per foot width.

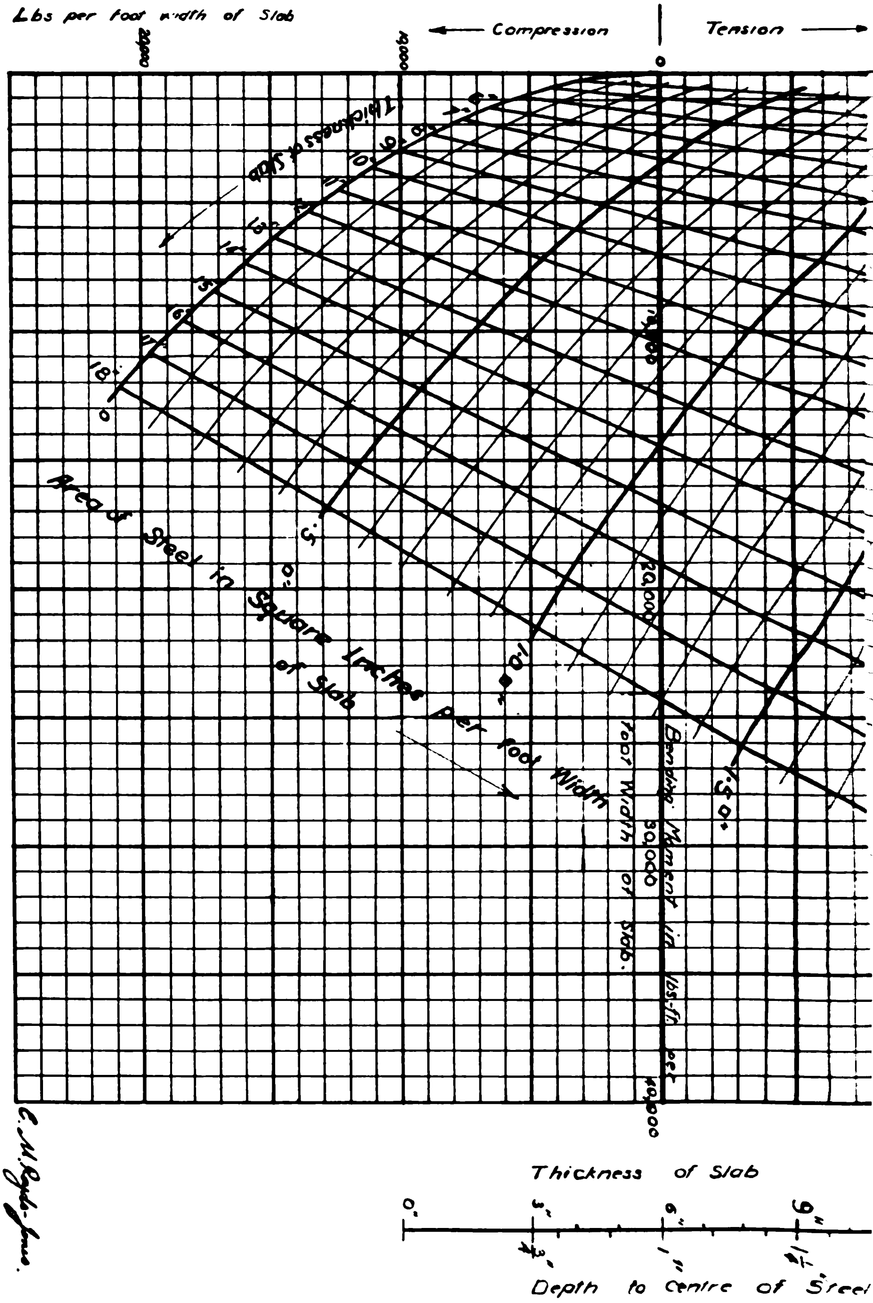
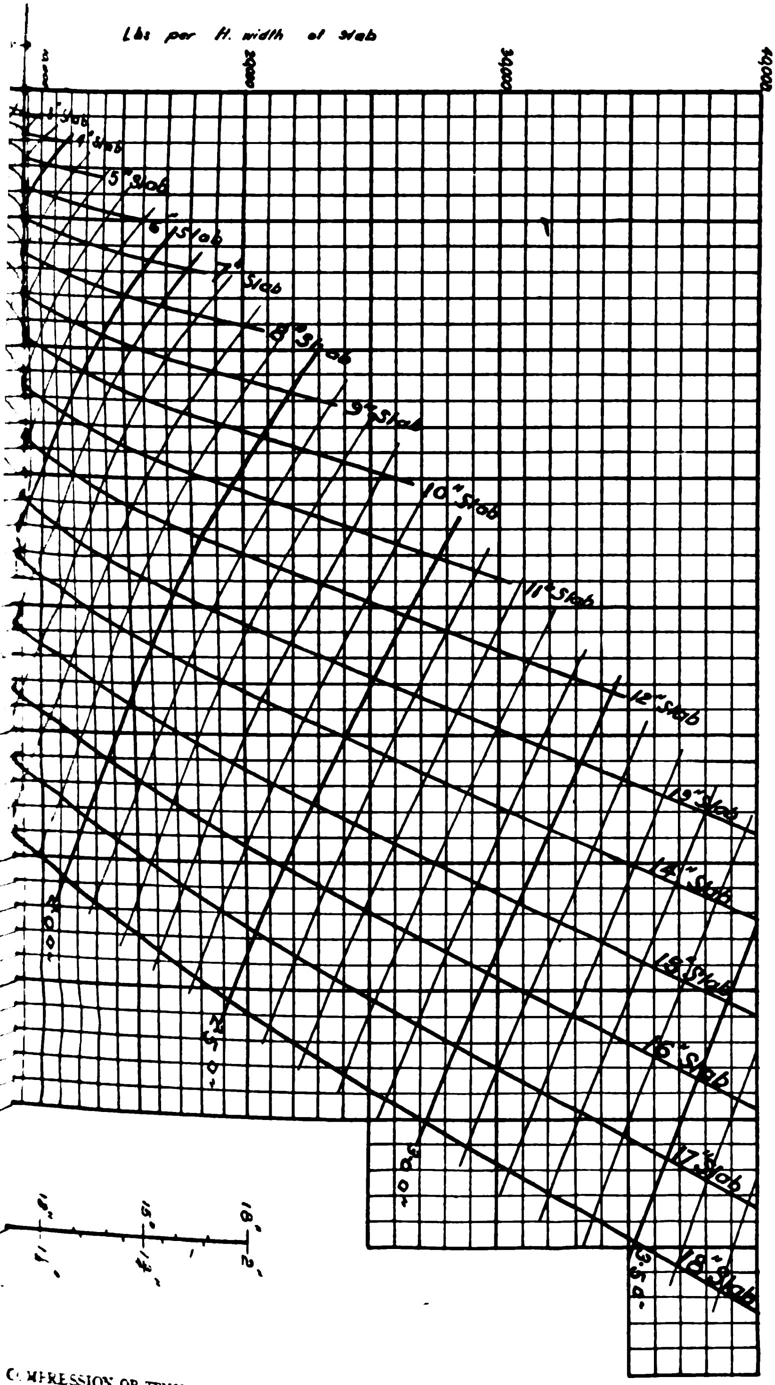
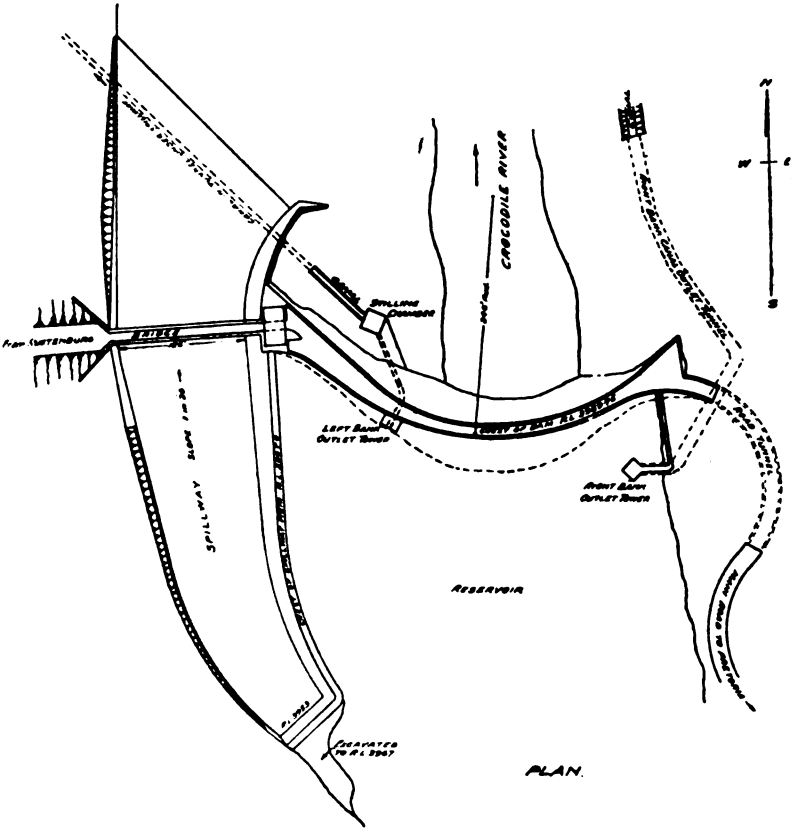


CHART FOR BEAMS SUBJECTED

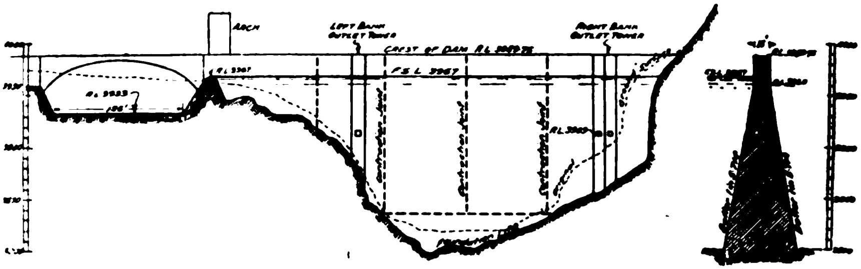
CHART FOR DESIGNING BEAMS.



COMPRESSION OR TENSION. (*See p.* 83.)



PLAN.



SECTIONAL ELEVATION OF DAM.

MAX. CROSS SECTION OF DAM.

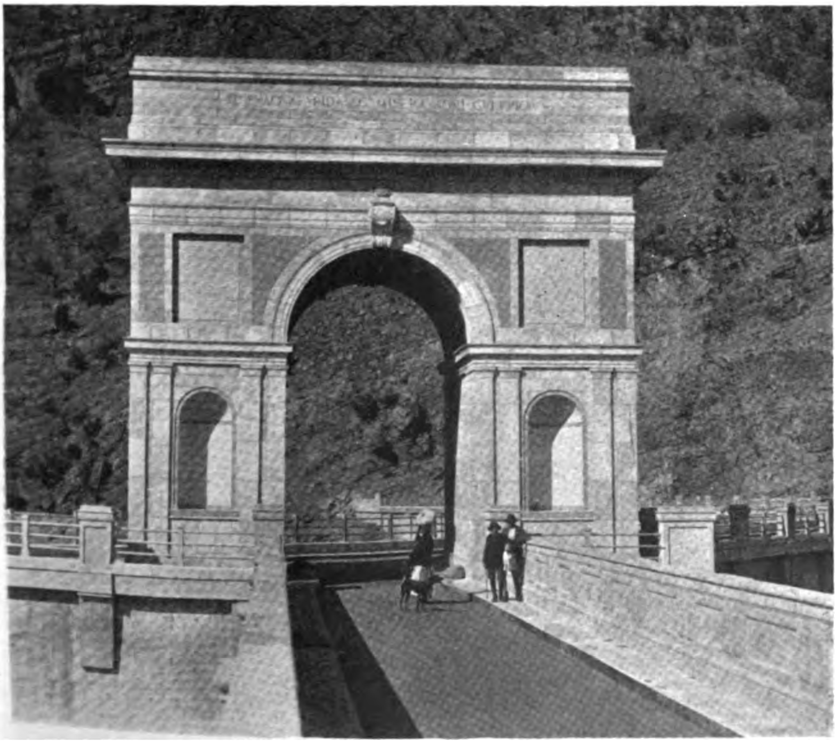
HARTEBEESTPOORT DAM, PRETORIA. (*See p.* 87.)

THE HARTEBEESTPOORT DAM, PRETORIA.

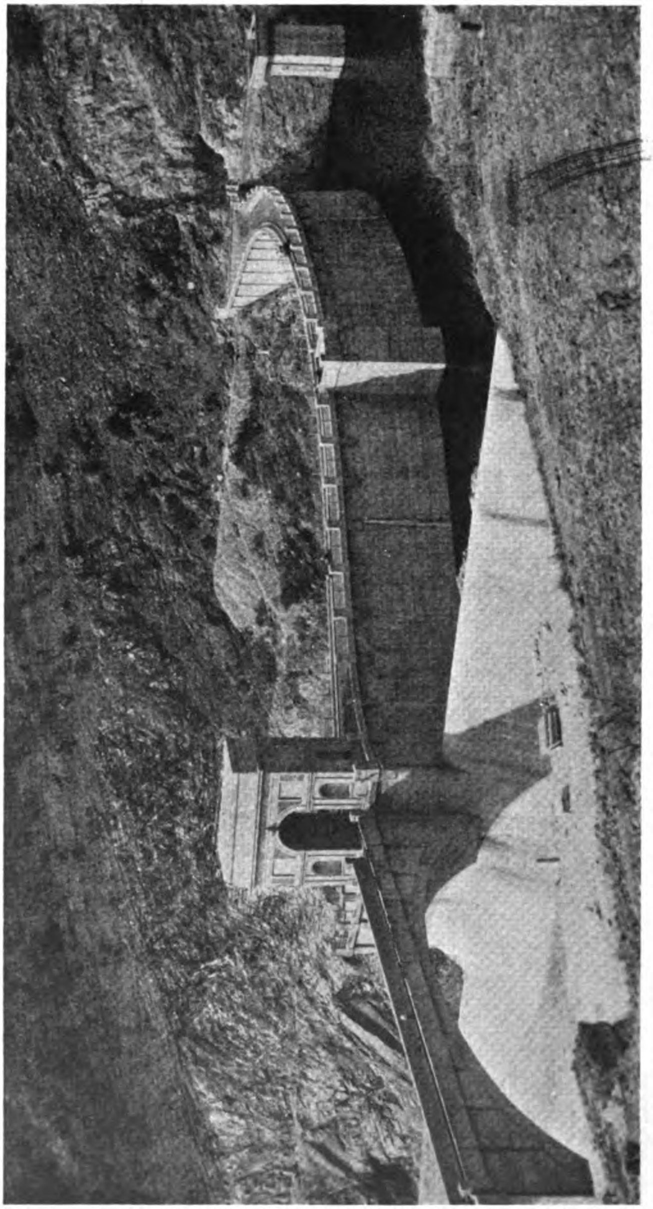
THE Hartebeestpoort Dam, Pretoria, has been engaging the attention of the authorities since 1902, but it was not until after the war that the scheme was energetically pushed forward. Towards the end of 1920, however, greater provision was made for proceeding with the work, and the cofferdams were completed and the river diverted by May, 1921. The foundations were excavated and the first concrete placed in July, 1921, and by September the wall had been brought 6 ft. above the river bed. From that date rapid progress was made, and the road over the top of the dam was opened in September, 1923.

The " poort " is situated about 23 miles in a direct line west of Pretoria. At the site the range consists of quartzites with a northerly dip of about 30 degrees. A fault line lies east of the poort and passes under the site of the dam at a depth about 500 ft. below river level and does not affect the safety of the dam. The quartzite is compact with widely-spaced joint planes and thin intrusions of igneous rock. On the east the rock is hard and suitable for crushing for concrete, but on the west the cohesion of the quartz grains is so poor that they can be separated with the fingers. Owing to a hard outside crust this was not discovered till after the work was started, and in consequence the material excavated from the spillway, which is on the west, could not be used for concrete, a quarry being opened on the east. Abundance of good sand was found in the river bed just below the dam site.

The elevation of the river bed above sea level is about 3,827 ft. The summer temperature is very high and the winters are cold, though frosts are not frequent. The drainage area above the dam is about 1,560 square miles coming down from the Witwatersrand and Witwaters-



CONCRETE ARCH ON THE HARTEBEESTPOORT DAM.



DAM SPILLWAY AND ABUTMENT ARCH, HARTEBEESTPOORT, PRETORIA, FROM LEFT BANK.

berg. Of this area about 320 square miles are dolomite, which yields a considerable permanent supply, part of which is absorbed by existing irrigation. By Act of Parliament no other storage works can be built in the drainage area and 600 million cu. ft. must be passed per annum as compensation to lower owners. The maximum flood recorded is estimated at about 150,000 cusecs. The water is comparatively free from silt.

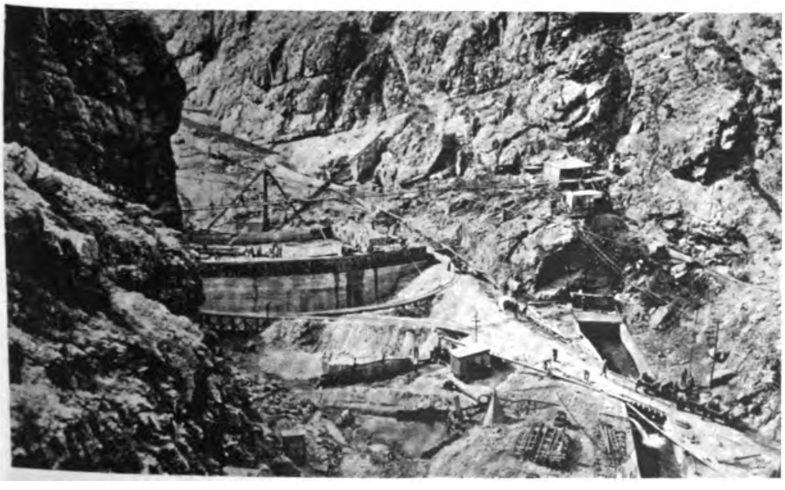
The gross storage capacity to the crest level of the waste weir is 136,241 acre feet and the net storage above outlet level 123,206 acre feet. The capacity can be increased very much at a later date by placing movable gates on the spillway weir.

Less than 10 per cent. of the gross storage is sacrificed in the 82 ft. from outlet level to river bed level, the level of the outlets having been fixed in order to get the canals through two commanding "neks."

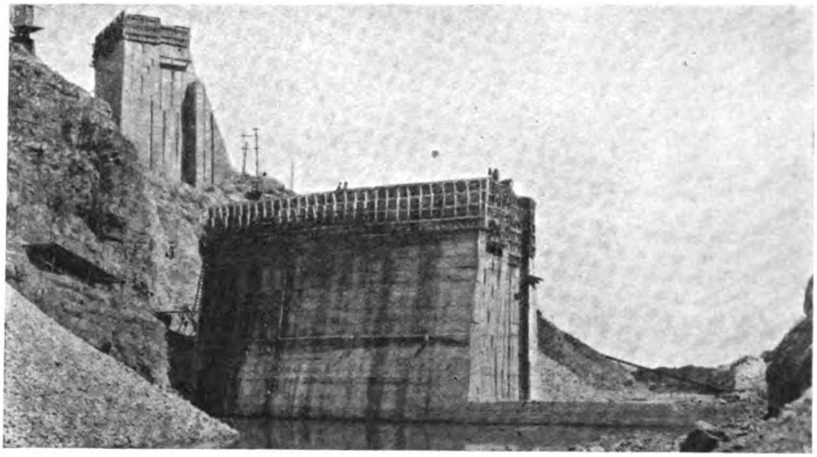
The area submerged at full supply level is about 6·7 square miles. Rights to store have been acquired to a level at which the area is 9·2 square miles.

The dam is of concrete. The original design was for a gravity section which would have required a width of about 140 ft. at lowest foundation level. This was altered early in 1921 to a varying radius arch dam with bottom width of only 73 ft. in order to effect economy in concrete and enable the foundations below river level to be got in during one dry-weather season.

The cofferdams were far advanced when the change of design was made; otherwise, it might have been advisable to shift the site of the dam farther upstream so as to get a better abutment against the mountain on the west side. As will be seen from the section, whereas the east bank is steep to above the top of the dam, the west bank flattens out before the top is reached. As a deep trough spillway had to be excavated on the west to a floor level of about 3,932·75 and the top of the dam is at 3,989·75, about 57 ft. of the top part of the dam was left "in the air." Consequently a very heavy abutment had to be provided on this side to take the thrust of the arch. While the upstream face was kept circular throughout an angle of 73 degrees (at the top), the down stream face was brought out on the west by means of short transition curves into a wide tangential abutment. At the bottom the radius to the upstream face was 148 ft., the width of the base at the centre 73 ft., and the radius to the downstream face 75 ft. From the base upwards the radii were increased to fit the central section which had both faces equally tapering upstream and downstream at 1 in 5·714 to the level 3,960. Above this level the faces are vertical and 15 ft. apart (top of solid parapet 3,989·75). The radius of the top section is 240 ft. to the upstream face. The maximum stress as



HARTEBEESTPOORT DAM (September 8, 1921).



HARTEBEESTPOORT DAM, LOOKING DOWNSTREAM (February 2, 1922).

calculated by the short formula is 13·3 tons/sq. ft., by the long formula 14·9 tons/sq. ft., on the assumption of pure arch action unrestrained by other forces. Calculations based on Craeger's method of treatment in which the arch is assumed restrained at the base, and the vertical beam capable of rotation about the base, give a maximum stress of 19·4 tons/sq. ft. The level of the plane at which maximum stress occurs is higher in the case of the short formula than for the long formula and higher still in the case of the restrained arch. Four radial contraction joints were provided above the level 3,835 at intervals of from 64 to 78 ft. The massive ornamental arch and the spillway bridge contribute a little towards the strength of the west abutment. The height from lowest foundation level (3,795) to top of solid parapet (3,989·75) is 194·75 ft.

The water has risen continuously in the dam, and at the end of September, 1923, it stood at the level of 3,953·3, spillway level being 3,967. Special arrangements have been made for measuring any deflection in the dam.

The drop to the river will be utilised to drive a small hydro-electric plant for electric light and pumping near the dam. The outlet on the west passes through the dam wall by means of a 5 ft. diameter cast-iron pipe embedded in the concrete. At the upstream end an emergency roller gate, 5 ft. diameter, works in a tower built against the dam and at the down stream end the pipe divides into three smaller pipes, the two outer ones being controlled by 24 in. gate valves and the central one by a 30 in. diameter gate valve, discharging against reinforced concrete walls. The west furrow has a capacity of 150 cusecs and passes under the spillway.

The spillway is cut as a trough on the west. The weir is built on the edge of the excavation with crest at 3,967 and its total length is 421 ft. 6 in. The face of the cliff below the spillway down to level about 3,920 was coated with gunite. At the upper end the level of the spillway floor is 3,953 and its width 56 ft. From there it falls at a slope of 1 in 20 and widens to a width of 125 ft. at the bridge. The floor is lined with concrete approximately 3 ft. thick near the weir wall and 18 in. at the far side. The side against the weir is at a slope of ½ to 1 and is lined with concrete. The far side is lined with a low wall which rises near the bridge. Weeper holes pierce the concrete, which is reinforced under the bridge. The bridge over the spillway is reinforced and has a clear span of 141 ft. 6 in.

The ornamental concrete archway is 41 ft. high, and roughly follows the proportions of the Arc de Triomphe in Paris. The niches and panels carry blue and buff tiles and mottoes are moulded in large letters.

Mr. J. L. Hill has been chief engineer from 1921, and the following have acted as resident engineers: Mr. G. T. Ritchie, Mr. W. Cooper, Mr. F. W. Scott, and Mr. B. G. Twycross.

MOMENTS IN TWO-SPAN CONTINUOUS BEAMS WITH VARIOUS SPAN RATIOS.

By CHARLES S. GRAY, B.Sc.(Eng.), A.M.I.Struct.E.

THE tables relating to bending moments in continuous beams which are to be found in most text-books on reinforced concrete are usually for those cases in which the spans are all equal in length—a condition which is often violated in practice.

This article considers beams of two spans only, and gives values of the bending moments at the support and in both spans for all cases of uniformly distributed loading where the ratio of spans varies from 1 : 1 to 1 : 0·1; but ratios greater than 1 : 0·6 are not commonly used.

Referring to *Fig.* 1, let the two spans be of length l and l_1 respectively, and the load be w per foot run of beam. Then the heights of the free bending moment diagrams on the two spans will be $\frac{wl^2}{8}$ and $\frac{wl^2_1}{8}$.

Adopting the usual form of Clapeyron's equation for beams with the same moment of inertia,* we get that—

$$2M(l+l_1) = 6\left\{\frac{Ax}{l} + \frac{A_1x_1}{l_1}\right\} \qquad \text{(i)}$$

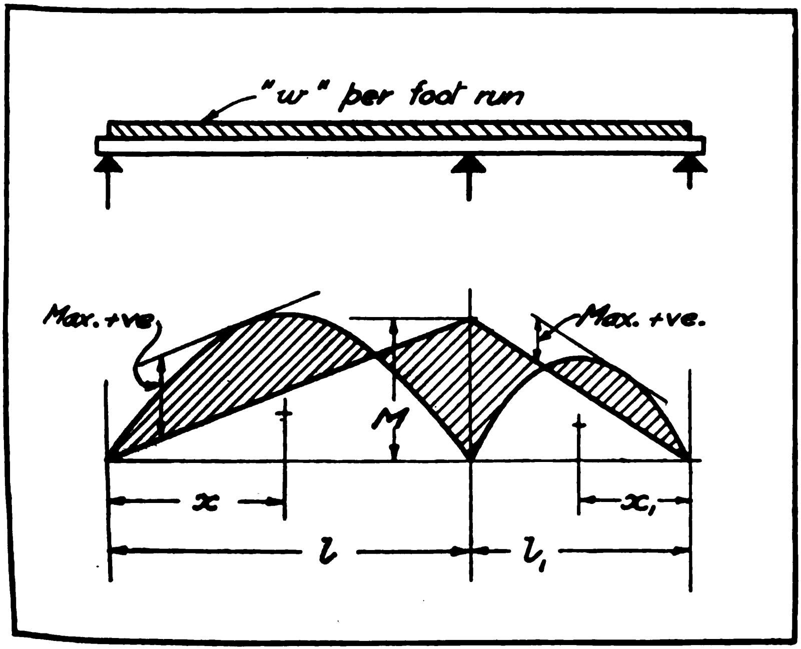


FIG. 1.

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* This will be approximated to in practice since the size of the beam will probably be determined by the moments in the longer span and the same cross-section adopted throughout.

where M = Negative moment at support,
A, A_1 = Areas of respective free bending moment diagrams,
x, x_1 = Distances of centres of gravity of free moment diagrams from outer supports.

Then we get—

$$A = \frac{wl^3}{12},\quad A_1 = \frac{wl_1^3}{12}$$

$$x = \frac{l}{2},\quad x_1 = \frac{l_1}{2}$$

But if $wl = W$ (i.e. if W = total load on span l) then $wl_1 = \frac{l_1W}{l}$ since w is assumed the same in both cases.

Substituting now we have—

$$A = \frac{Wl^2}{12} \text{ and } A_1 = \left(\frac{l_1W}{l}\right).\frac{l_1^2}{12}.$$

Inserting these values in equation (i) we get—

$$2M(l + l_1) = 6\left\{\frac{Wl^3}{24l} + \left(\frac{l_1W}{l}\right).\frac{l_1^3}{24l_1}\right\}$$

$$= 6\left\{\frac{Wl^2}{24} + \left(\frac{l_1W}{l}\right).\frac{l_1^2}{24}\right\}$$

$$\therefore M = \frac{3}{(l + l_1)}\left\{\frac{Wl^2}{24} + \left(\frac{l_1W}{l}\right).\frac{l_1^2}{24}\right\} \qquad . \quad . \quad \text{(ii)}$$

We are now in a position to calculate M for various ratios of $l_1 : l$ and various conditions of loading. There are three possible ways of loading the beams:—

(*a*) Both spans loaded.
(*b*) Long span loaded (span l),
(*c*) Short span loaded (span l_1),

and these will be considered in the order given.

(*a*) **Both Spans Loaded.**

(1) $l_1 = l$.

This is the case commonly quoted, and by substitution we get—

$$4M = \frac{Wl}{2}$$

$$\therefore M = \frac{Wl}{8} = {\cdot}125Wl.$$

Height of free moment diagram = $\cdot125Wl$.

(2) $l_1 = \cdot9l$.

$$\therefore M(1{\cdot}9l) = 3\left\{\frac{Wl^2}{24} + {\cdot}729\left(\frac{Wl^2}{24}\right)\right\}.$$

$$\therefore M = 1{\cdot}58Wl\{{\cdot}0416 + ({\cdot}729 \times {\cdot}0416)\}.$$

$$= 1{\cdot}58Wl\{{\cdot}0416 + {\cdot}0304\}$$

$$= 1{\cdot}58Wl \times {\cdot}0720.$$

$$\therefore M = {\cdot}114Wl.$$

Height of free bending moment diagram on long span $= \cdot 125Wl$.

Height of free bending moment diagram on short span $= \cdot 125Wl \times \left(\frac{l_1}{l}\right)^2$

$$= \cdot 125Wl \times \cdot 81.$$
$$= \cdot 101Wl.$$

(3) $l_1 = \cdot 8l$.

$$\therefore\ M = \frac{3}{1\cdot 8l}\left\{\frac{Wl^2}{24} + \cdot 512\left(\frac{Wl^2}{24}\right)\right\}$$
$$= 1\cdot 67Wl\{\cdot 0416 + \cdot 0214\}$$
$$= 1\cdot 67Wl \times \cdot 063.$$
$$\therefore\ M = \cdot 105Wl.$$

Height of free bending moment diagram on long span $= \cdot 125Wl$.
Height of free bending moment diagram on short span $= \cdot 125Wl \times \cdot 64$.
$= \cdot 080Wl$.

By similar substitutions we get the following results.

(4) $l_1 = \cdot 7l$.
$M = \cdot 099Wl$.

Height of free bending moment diagram on short span $= \cdot 061Wl$.

(5) $l_1 = \cdot 6l$.
$M = \cdot 095Wl$.

Height of free bending moment diagram on short span $= \cdot 045Wl$.

(6) $l_1 = \cdot 5l$.
$M = \cdot 094Wl$.

Height of free bending moment diagram on short span $= \cdot 031Wl$.

(7) $l_1 = \cdot 4l$.
$M = \cdot 095Wl$.

Height of free bending moment diagram on short span $= \cdot 020Wl$.

(8) $l_1 = \cdot 3l$.
$M = \cdot 099Wl$.

Height of free bending moment diagram on short span $= \cdot 011Wl$.

(9) $l_1 = \cdot 2l$.
$M = \cdot 105Wl$.

Height of free bending moment diagram on short span $= \cdot 005Wl$.

(10) $l_1 = \cdot 1l$.
$M = \cdot 114Wl$.

Height of free bending moment diagram on short span $= \cdot 00125Wl$.

We next require to know the maximum positive bending moments near the centres of the spans, and these are found as follows :—

Taking case (1) again, and taking a section distant x from the outer support, we have :

Negative bending moment at that section due to support bending moment $= \cdot 125W \times x$.

The positive bending moment due to the beam considered as simply supported $= \cdot 5Wx - \cdot 5wx^2$.

Then the total bending moment at that point is given by

$$\cdot125Wx - \cdot5Wx + \cdot5wx^2 \quad . \quad . \quad . \quad . \quad \text{(iii)}$$

This is a maximum when

$$\frac{d}{dx}(\cdot125Wx - \cdot5Wx + \cdot5wx^2) = 0.$$

Replacing W by wl and removing the common factor w,

$$\text{i.e. when } \frac{d}{dx}\,(\cdot125lx - \cdot5lx + \cdot5x^2) = 0$$

$$\text{i.e. when } \cdot125l - \cdot5l + x = 0$$

$$\text{i.e. when } x = \cdot375l.$$

Substituting this value in equation (iii) we get maximum positive bending moment $= \cdot0703Wl$.

(2) $l_1 = \cdot9l$.

Considering long span. The bending moment is a maximum when $\cdot114l - \cdot5l + x = 0$, i.e. when $x = \cdot386l$.

We then get maximum positive bending moment $= \cdot074Wl$.

Considering the short span and working for convenience in terms of l_1, the support bending moment becomes $\frac{\cdot114}{\cdot81}Wl_1 = \cdot141Wl_1$.

Then the positive moment is a maximum when $\cdot141l_1 - \cdot5l_1 + x = 0$; i.e. when $x = \cdot359l_1$.

We then get by substitution in equation (iii)—

$$M = \cdot0646Wl_1 = \cdot0646 \times \cdot81Wl.$$
$$= \cdot0523Wl.$$

The following results are then obtained in a similar manner:—

(3) $l_1 = \cdot8l$.

Maximum positive moment in long span $= \cdot078Wl$.
Maximum positive moment in short span $= \cdot036Wl$.

(4) $l_1 = \cdot7l$.

Maximum positive moment in long span $= \cdot080Wl$.
Maximum positive moment in short span $= \cdot022\ Wl$.

(5) $l_1 = \cdot6l$.

Maximum positive moment in long span $= \cdot082Wl$.
Maximum positive moment in short span $= \cdot0096Wl$.

(6) $l_1 = \cdot5l$.

Maximum positive moment in long span $= \cdot0825Wl$.
Maximum positive moment in short span $= \cdot0019Wl$.

(7) $l_1 = \cdot4l$.

Maximum positive moment in long span $= \cdot082Wl$.

For ratios greater than this, the bending moment on the short span is totally negative, the maximum value being at the support.

(8) $l_1 = \cdot3l$.

Maximum positive moment in long span $= \cdot080Wl$.

(9) $l_1 = \cdot 2l$.

Maximum positive moment in long span $= \cdot 078Wl$.

(10) $l_1 = \cdot 1l$.

Maximum positive moment in long span $= \cdot 074Wl$.

(*b*) **Long Span only Loaded** (span l).

In this case equation (ii) reduces to

$$M = \frac{3}{(l + l_1)}\left\{\frac{Wl^2}{24}\right\}$$

M being thus found for each ratio of l_1/l, the maximum positive bending moment on the long span can be found as before indicated. The bending moment over the short or unloaded span is of course negative. The following are the values obtained :—

Case.	Negative Moment at Support.	Positive Moment in Long Span.
1	$\cdot 0625\ Wl$	$\cdot 0957\ Wl$
2	$\cdot 0658\ Wl$	$\cdot 094\ Wl$
3	$\cdot 0696\ Wl$	$\cdot 093\ Wl$
4	$\cdot 0734\ Wl$	$\cdot 091\ Wl$
5	$\cdot 0779\ Wl$	$\cdot 088\ Wl$
6	$\cdot 0832\ Wl$	$\cdot 086\ Wl$
7	$\cdot 0895\ Wl$	$\cdot 083\ Wl$
8	$\cdot 0964\ Wl$	$\cdot 080\ Wl$
9	$\cdot 104\ Wl$	$\cdot 077\ Wl$
10	$\cdot 114\ Wl$	$\cdot 074\ Wl$

Free moment on long span throughout $= \cdot 125Wl$.

(*c*) **Short Span only Loaded** (span l_1).

Equation (ii) now becomes $M = \dfrac{3}{(l + l_1)}\left\{\left(\dfrac{l_1W}{l}\right)\dfrac{l_1{}^2}{24}\right\}$ from which we find the following values for M and in turn the values of the positive moments.

Care.	Free Moment on Short Span.	Negative Moment at Support.	Positive Moment in Short Span.
1	$\cdot 125\ Wl$	$\cdot 0625\ Wl$	$\cdot 0957\ Wl$
2	$\cdot 101\ Wl$	$\cdot 048\ Wl$	$\cdot 078\ Wl$
3	$\cdot 080\ Wl$	$\cdot 0357\ Wl$	$\cdot 063\ Wl$
4	$\cdot 061\ Wl$	$\cdot 0252\ Wl$	$\cdot 049\ Wl$
5	$\cdot 045\ Wl$	$\cdot 0168\ Wl$	$\cdot 037\ Wl$
6	$\cdot 031\ Wl$	$\cdot 0104\ Wl$	$\cdot 026\ Wl$
7	$\cdot 020\ Wl$	$\cdot 0057\ Wl$	$\cdot 017\ Wl$
8	$\cdot 011\ Wl$	$\cdot 0026\ Wl$	$\cdot 010\ Wl$
9	$\cdot 005\ Wl$	$\cdot 0008\ Wl$	$\cdot 0046\ Wl$
10	$\cdot 00125\ Wl$	$\cdot 00001\ Wl$	$\cdot 0012\ Wl$

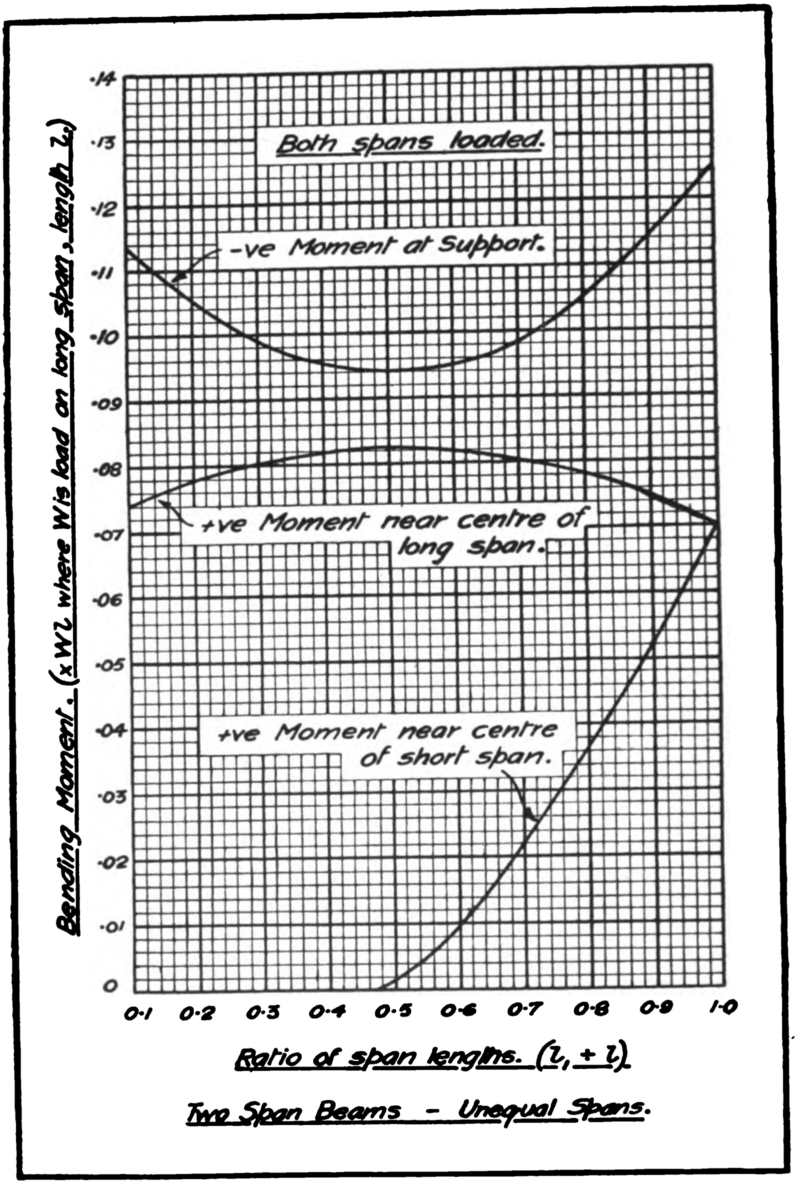

Both spans loaded.
-ve Moment at Support.
+ve Moment near centre of long span.
+ve Moment near centre of short span.
Bending Moment. (x Wl where W is load on long span, length l.)
·14
·13
·12
·11
·10
·09
·08
·07
·06
·05
·04
·03
·02
·01
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
Ratio of span lengths. (l₁ ÷ l)
Two Span Beams - Unequal Spans.

Fig. 2.

The whole of the values thus found have been collected and are given in the following table.

Two Span Beams—unequal spans.
l = long span, l_1 = short span.

All ordinates of bending moment to be multiplied by Wl where W is load on long span l.

1	2	3	4	5	6	7	8	9
Ratio l_1/l	Free Bending Moment on Short Span.	Both Spans loaded.			Long Span only loaded.		Short Span only loaded.	
		− At Support.	+ Long Span.	+ Short Span.	− At Support.	+ Long Span.	− At Support.	+ Short Span.
1·0	·125	·125	·0703	·0703	·0625	·0957	·0625	·0957
·9	·101	·114	·074	·052	·066	·094	·048	·078
·8	·080	·105	·078	·036	·0696	·093	·0357	·063
·7	·061	·099	·080	·022	·0734	·091	·0252	·049
·6	·045	·095	·082	·0096	·078	·088	·0168	·037
·5	·031	·094	·0825	·0019	·083	·086	·0104	·026
·4	·020	·095	·082	Negative	·0895	·083	·0057	·017
·3	·011	·099	·080	do.	·0964	·080	·0026	·010
·2	·005	·105	·078	do.	·104	·077	·0008	·0046
·1	·00125	·114	·074	do.	·114	·074	·00001	·0012

From this table three sets of curves have been plotted, *Fig.* 2 giving the moments for case (*a*), *Fig.* 3 giving those for case (*b*), and *Fig.* 4 those for case (*c*). In each case the ordinate of the diagram is to be multiplied by Wl where W is the load on the long span or span l. The curves refer both to dead and live uniform loads and the maximum bending moments due to a combination of these may be found as explained by the author in "Moments in Continuous Beams for Varying Ratios of Live Load to Dead Load" which appeared in the May, 1923, issue of this journal. To indicate the method by which the curves are used an example is given below :—

Continuous Beam.

Spans 20 ft. 0 in. and 15 ft. 0 in.—span ratio ·75.
Dead load = 600 lb. per foot run.
Live load = 1,500 lb. per foot run.

Dead Load Moments (both spans loaded).

Max. negative at support.	Max. positive in long span.	Max. positive in short span
·101Wl	·079Wl	·029Wl

(All values from Fig. 2.)

Live Load Moments.

Max. negative at support (both spans loaded, *Fig.* 2).	Max. positive in long span (both spans loaded, *Fig.* 2).	Max. positive in short span (Short span only loaded, *Fig.* 4).
·101Wl	·079Wl	·056Wl

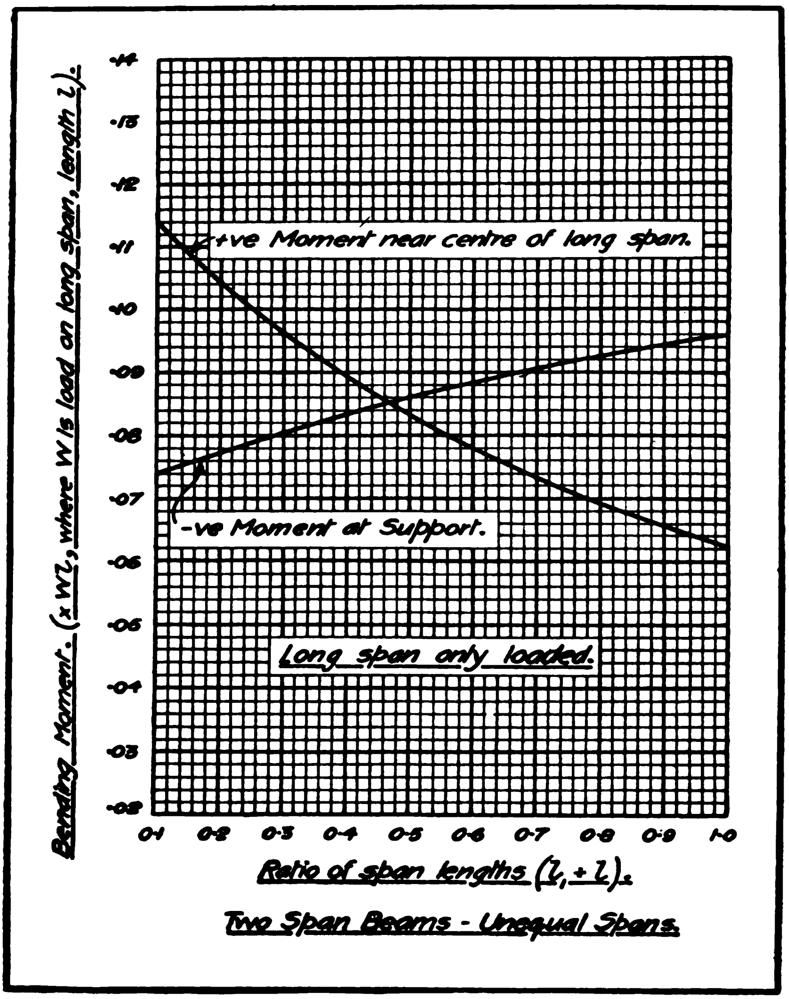

Bending Moment. (x Wl, where W is load on long span, length l).
·14
·13
·12
·11
·10
·09
·08
·07
·06
·05
·04
·03
·02
+ve Moment near centre of long span.
-ve Moment at Support.
Long span only loaded.
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
Ratio of span lengths ($l_1 \div l$).
Two Span Beams - Unequal Spans.

FIG. 3.

Ratio of live load to dead load = 2·5 : 1.

∴ Maximum moments to be designed for are as follows:

Negative at support.	Positive in long span.	Positive in short span.
·101Wl	·079Wl	$\left(\frac{\cdot029 + 2\cdot5 \times \cdot056}{3\cdot5}\right)Wl$ $= \cdot048Wl$

Where $W = 2{,}100 \times 20$ lb.
$= 42{,}000$ lb.
and $l = 20$ ft. 0 in.

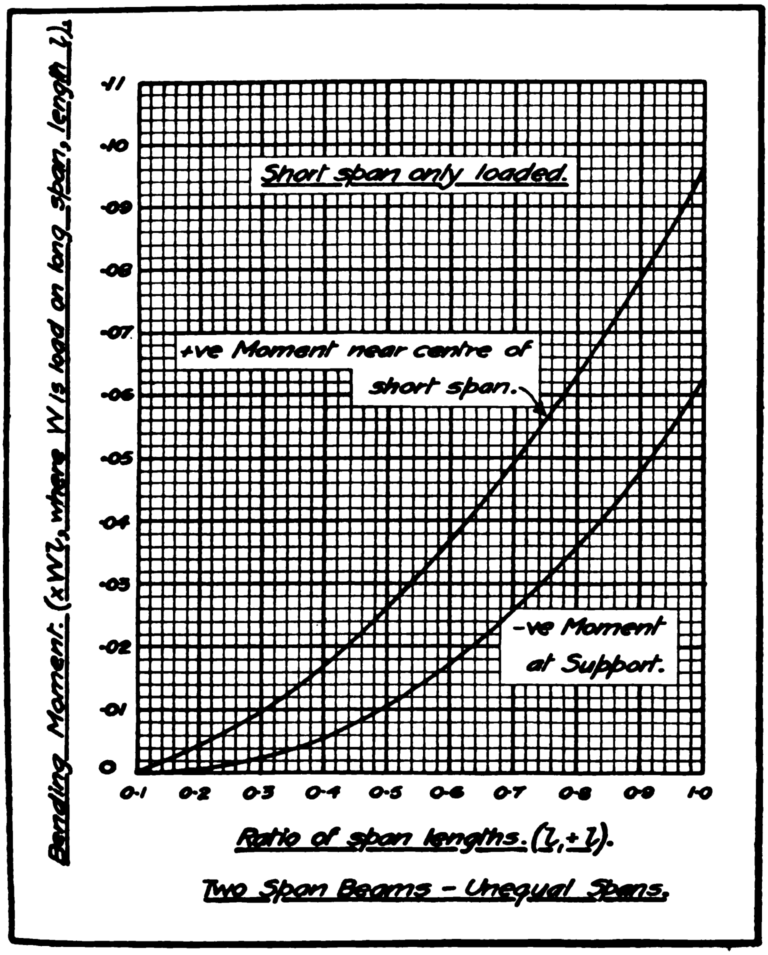
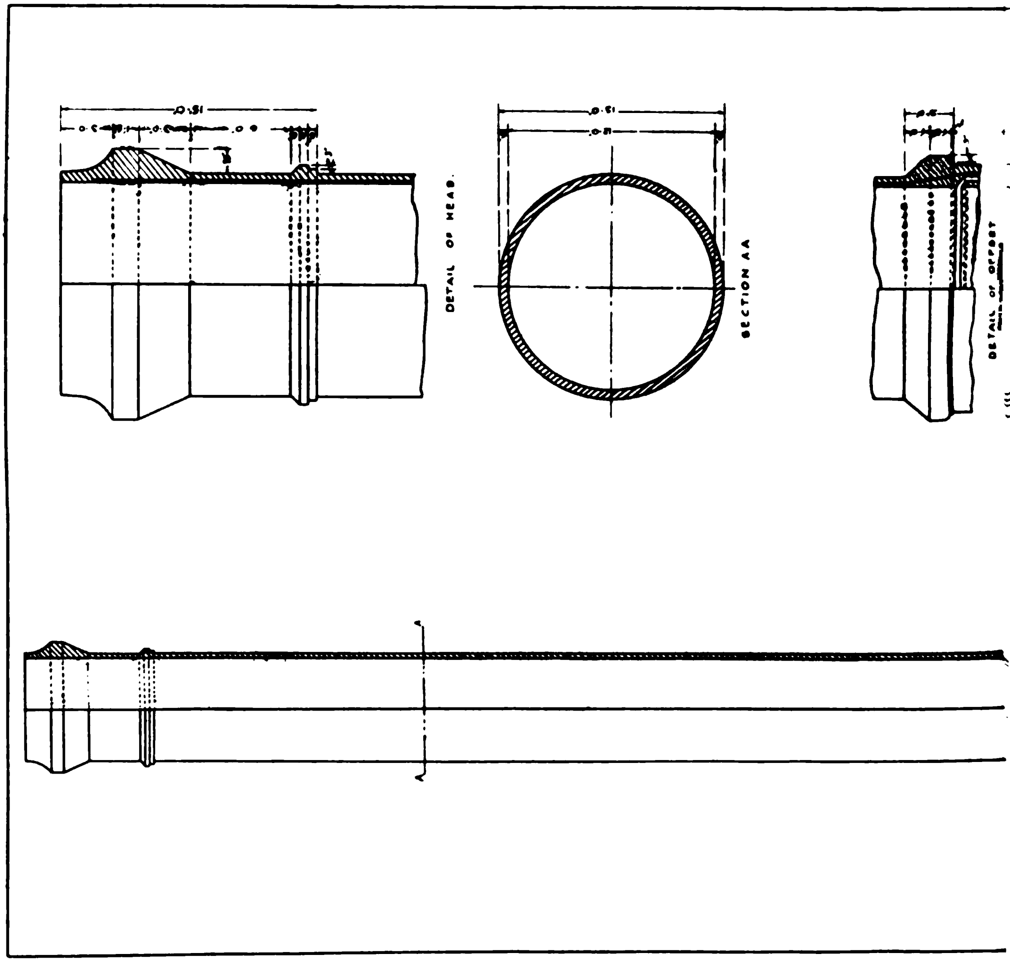
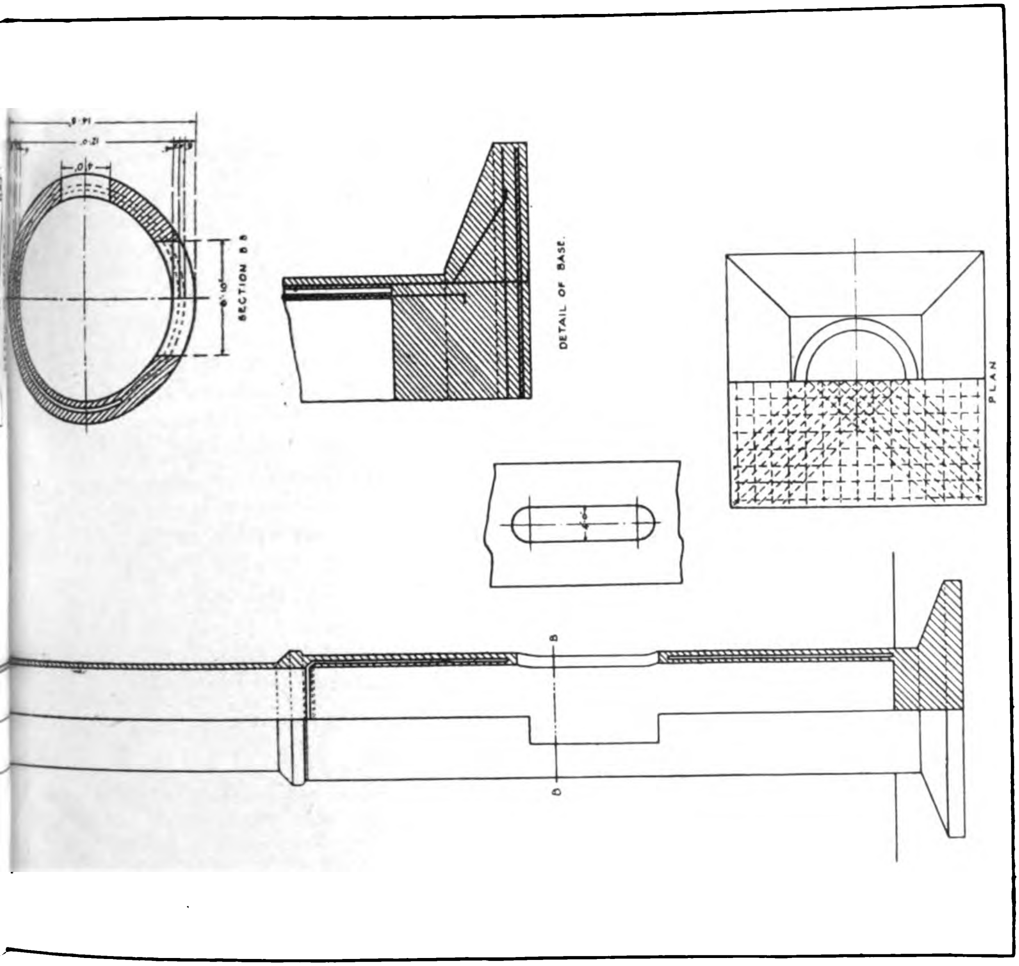


Fig. 4.



REINFORCED CONCRETE CHIMNEY AT PORTLAND, OREGO



OR THE PORTLAND GENERAL ELECTRIC COMPANY. (*See p.* 102.)

REINFORCED CONCRETE CHIMNEYS.

By E. R. MATTHEWS, M.Inst.C.E., F.R.S.(Ed.).

REINFORCED concrete has been used in this country in many forms of engineering construction, but its use in the construction of tall chimneys has been limited to perhaps a score of examples only. In America, however, over a thousand of such shafts have been built.

The advantages of this class of chimney are:—

(*a*) Economy in cost (there is a saving of about 20 per cent. as compared with brick shafts).

(*b*) Saving of space.

(*c*) Much less weight than brick shafts (which require to have a wide and heavy base).

(*d*) Greater stability, having no joints.

(*e*) Freedom from repairs.

(*f*) Rapidity of execution of work.

(*g*) Eminently suitable for treacherous foundations.

(*h*) Simplicity of design.

The drawings on pp. 101–102 illustrate an American chimney erected at Portland, Ore., for the Portland General Electric Co. It is 230 ft. by 12 ft. inside measurement. The slab foundation is 30 ft. sq., and the shell is reinforced by vertical bars and horizontal rings on inner and outer sides, the foundation slab is reinforced as shown. The bottom of the foundation slab is 8 ft. below the ground level. The outside diameter of the lower portion of the chimney is 14 ft. 8 in., the inside diameter being 12 ft., and built with a cavity; the thickness of the upper portion of the shaft is 6 in., terminating with a heavy cornice. Double-walls are built at the base, with a 4-in. cavity, the outer wall is 8 in. and the inner 4 in. in thickness.

Great care should be taken in the choice of the aggregate; only the best procurable should be used, bearing in mind that certain aggregates will withstand the action of hot gases better than others.

ESTIMATING FOR CONCRETE WORK.

In the course of a paper read before a meeting of the Manchester Branch of the Institute of Builders last month, Mr. T. Sumner Smith, F.S.I., F.I.Ar., chartered quantity surveyor, of Manchester, put forward some interesting and original views on the question of estimating for concrete and excavation.

In some preliminary remarks he said: The principal methods of estimating might be said to be:

(1) Pricing from correctly ascertained data of a like kind;

(2) Pricing from data of a like kind, confirmed and checked by empirical methods founded upon experience.

The former might be taught and learned just as any other subject, and presented no great difficulties. The latter was more difficult to teach and learn; but it was possible, bearing in mind that anything might be taught successfully when its application was understood and that it might be acquired by the right aptitude and industry. Both were somewhat similar, but the difference was in the kind of experience.

Of the two, the former method was the more scientific and should produce accurate estimates as nearly alike as peas in a pod. It, however, did not mean that experience was not necessary, for success would depend on the skill of the estimater. But this experience was of a different nature from that of the latter, inasmuch as it relied upon scientific rather than empirical methods. Its fundamentals rested upon a sure foundation.

As regarded the latter method, often enough it might be that an estimater skilfully blended the two—data which he did not feel he could rely upon absolutely, and experience which was no certain guide to accuracy. He might use such data as he had to arrive at the price, weigh and check the result, and modify according to his judgment and by his experience. The quality of the blend was the measure of his attainments. It was nevertheless empirical, and in all such estimates there was an individual flavour.

It might, and probably would, be the combination of the essentials of these two methods that would give the most satisfactory results; that was, pricing, from correctly ascertained data and its application founded upon the right kind of experience. But that stage had scarcely yet been reached.

ANALYSIS OF THE CONSTITUENTS OF CONCRETE.

Dealing with the essential principles underlying estimating for building works, he said analysis was one of the most important. Particularly so did estimating call for this, since by the present system the modes of measurements were expressed, as a general rule, for artificers' work in terms different from the purchase terms of materials; further, artificers' work might be composed of several and distinct kinds of materials whose values differed, and it might sometimes happen that their purchase terms differed. A cubic yard of cement concrete, for example, was invariably made up of broken bricks or stone, shingle or gravel, ashes or coke breeze, or slag, together with sand and cement and water. The purchase terms of broken bricks, etc., and sand might either be by weight or by volume, whilst the purchase term of cement was by weight, and that of water by the gallon. And the value might vary in each case, even though bought on the same purchase terms. Similarly, there might be various kinds of labour employed whose rates of remuneration differed. Then again, railway rates and cartage rates might vary—the price per ton of sand would obviously be less than the price per ton of cement, as the latter might require protection from inclement weather. Also, although sand might be purchased at a rate on the terms of so much per cubic yard, the railway rate was invariably based upon the terms of so much per ton. Here, then, was a simple commodity or compound article—cement concrete—which on analysis for the purpose of estimating presented numerous problems for solution. Analysis was the first step in arriving at the price.

Taking as an example a cubic yard of cement concrete composed of 5 parts broken brick, 1 part sand, and 1 part cement, the lecturer examined in detail the problems as they presented themselves, and gave illustrations of methods by which they might be solved with a view of ultimately arriving at the price per cubic yard.

The quantities of materials required to make a cubic yard of cement concrete were, he said, an important factor of the cost. It would be wrong to assume that the quantity of broken bricks in this case plus the quantity of sand and quantity of cement was equal to the volume of the finished concrete. Thus, 5 cubic yards of broken bricks, 1 cubic yard of sand, and 1 cubic yard of cement would not make 7 cubic yards of cement concrete, since the grains of sand and cement filled, to a certain extent, the spaces or voids between the broken bricks. It was also incorrect, on the other hand, to assume the quantity of broken bricks alone as being exactly equal to the volume of the concrete, because it depended upon whether the amount of sand and cement introduced was equal to the actual voids. In the example given the broken bricks amounted to 1¼ cubic yard in volume to the finished cubic yard of cement concrete.

Water could be taken as an illustration. Pure water at a given temperature—39·2° F.—was at its greatest density, and one gallon weighed 10 lbs., and 6·25 gallons or 62·5 lbs. equalled approximately one cubic foot. Water at its greatest density was neither expandable nor compressible.

The first problem, therefore, in arriving at the quantity of materials in a cubic yard of cement concrete was that of voids. How was the amount of voids to be ascertained and determined?

In Table I was given an assumed amount of materials required to make a cubic yard of finished cement concrete.

TABLE I

ASSUMED AMOUNT OF MATERIALS REQUIRED TO MAKE A CUBIC YARD OF FINISHED CEMENT CONCRETE.

Materials	Proportion by parts.	Proportion by volume in c. ft.	Proportion by weight in cwts.
Broken bricks .	5	32·4	22·2
Sand . . .	1	6·29	5·36
Cement . .	1	6·29	4·9
		44·98	32·46
Water . . .	25 galls.	4·00	2·23
	Totals	48·98	34·69

The figures in Table I must not be accepted as accurate, but to suit the purpose they need only be assumed as being accurate.

The simplest rule for ascertaining the approximate quantities of materials for a cubic yard of cement concrete was obtained by dividing the constant **41·8** by the sum of the parts of all the ingredients (when the cement was expressed as one part) and the quotient would be the number of cubic feet of cement for one cubic yard of concrete; for sand the quotient should be multiplied by the number of parts of sand, which would give the number of cubic feet of sand for one cubic yard of concrete; and for aggregate the quotient should be multiplied by the number of parts of aggregate, which would give the number of cubic feet of aggregate for one cubic yard of concrete.

Let C = one part cement.
,, S = number of parts of sand.
,, A = number of parts of aggregate.

Then:

$$\frac{41{\cdot}8}{C+S+A} = C' = \text{Number of cubic feet of cement to one cubic yard of concrete.}$$

$$C' \times S = S' = \text{Number of cubic feet of sand to one cubic yard of concrete.}$$

$$C' \times A = A' = \text{Number of cubic feet of aggregate to one cubic yard of concrete}$$

Thus:—

$$\frac{41{\cdot}8}{C+S+A} = C' = \frac{41{\cdot}8}{7} = 5{\cdot}97 \text{ cubic feet (approx.).}$$

$$C' \times S = 5{\cdot}97 \times 1 = 5{\cdot}97 \text{ cubic feet (approx.).}$$

$$C' \times A = 5{\cdot}97 \times 5 = 29{\cdot}85 \text{ cubic feet (approx.)}$$

This gave a total of 41·79, which was slightly less than the amounts given in Table I. If using this rule about 5 per cent. should be added to all the materials when the coarse material was screened to uniform size, as it contained less solid matter in a given volume than an average size. When the coarse material contained a large variety of sizes so as to be quite dense, about 5 per cent. might be deducted from all the quantities.

VOIDS.

The determination of voids of a unit volume of aggregate had been ascertained in the past mainly by actual trial—by filling a water-tight box with 1 yd. cube of aggregate well wetted to avoid further absorption, and measuring the volume of water it was necessary to pour in to fill up all the interstices. The voids in sand were ascertained in a similar manner. In practice those void tests gave anything but satisfactory results. In the case of sand the moisture which the sand contained so affected its volume that the test was scarcely of any value. If the sand were dry, for example, a fine sand with grains of a uniform size would have about the same percentage of voids as a coarse sand with uniform grains; whilst, on the other hand, if sand when tested contained natural moisture, the amount of this varied so much from day to day that the original volume of the sand, and in fact the volume of the voids, might be affected to the extent of 10 per cent. An increase in the percentage of moisture increased the bulk of sand and also the voids up to a certain point.

The correct way to determine the voids of a unit of aggregate or sand was to ascertain the specific gravity of the materials, or the ratio of the weight of a given volume to the weight of the same volume of distilled water at a temperature of 62° F. For ordinary tests of aggregate and sand the water need not be distilled and might be at ordinary temperature—say from 60° to 80°.

For ordinary bricks the specific gravity was 1·90, and the weight per cubic foot 118 lbs. The specific gravity of sandstone might be taken as 2·6, and the weight of a solid cubic foot 160 lbs.

As a rule the voids in cement were not ascertained. Loose Portland cement averaged about 92 lbs. per cubic foot, but when packed tight it averaged about 115 lbs. Portland cement was assumed in standard proportions to weight 100 lbs. per cubic foot.

Specific gravity multiplied by 62·32 = weight of a cubic foot in lbs.: therefore weights of aggregate or sand divided by 62·32 gave specific gravity.

In the example shown in Table I the approximate weights of the respective materials were set out in Table II, together with their specific gravities, and also the weights of bricks, sandstone and cement with their specific gravities.

TABLE II

Assumed Weights, and the Specific Gravity of Materials in Table I, and Weight and Specific Gravity of Average Ordinary Bricks, Sandstone and Cement.

Materials.	Weight per cu. foot in Lbs.	Specific Gravity.
Broken bricks, 1½ in. to 2 in.	77	1·24
Sand, loose	95	1·52
Cement, loose . . .	88	1·41
Bricks, average . . .	118	1·9
Sandstone	160	2·6
Standard cement . .	193	3·1

From Table II the proportion of solids and voids might be deduced thus:—

$$\text{Aggregate}: \frac{77}{118} = \cdot 652 = \begin{matrix}65\cdot 2 \text{ solid.}\\ 34\cdot 8 \text{ voids.}\end{matrix}$$

$$\text{Sand}: \frac{95}{160} = \cdot 594 = \begin{matrix}59\cdot 4 \text{ solid.}\\ 40\cdot 6 \text{ voids.}\end{matrix}$$

$$\text{Cement}: \frac{88}{193} = \cdot 456 = \begin{matrix}45\cdot 6 \text{ solid.}\\ 54\cdot 4 \text{ voids.}\end{matrix}$$

It would be noted that in Table II the weight of a cubic foot of broken bricks, size 1½ in. to 2 in., had been taken at 77 lbs., loosely packed sand at 95 lbs., and cement at 88 lbs. It must not be assumed that these were accurate, they were given for the purposes of illustration. It might be taken for granted that no one set of figures would apply in every case, although averages might be obtained.

From Tables I and II could be determined the absolute volume of materials which were set out in Column in Table III. The absolute volume was obtained by multiplying the figure (take those in cubic feet) in Column F by the figure in Column I in Table III. Thus for broken bricks: 32·4 × 65·2 = 21·124 cubic feet. In other words, it required 21·124 cubic feet of solid brickwork to a finished cubic yard of concrete when the proportions were 5 : 1 : 1.

Table III combined Table I and Table II, but in addition it gave the absolute volume of materials in cubic feet and cubic yards (Column J).

TABLE III

A	B	C	D	E	F		G
Materials	Proportion by parts.	Volume of mortar in term of percentage of absolute volume of Aggregate.	Weight of material in Lbs.	Specific Gravity.	Proportion by Volume.		Proportion by Weight.
Kind.	Parts.	Percent.	Cu. Ft.		Cu. Ft.	Cu. Ft.	Cwts.
Broken bricks . .	5		77·0	1·24	32·4	1·20	22·2
Sand	1	31·0	95·0	1·52	6·29	·233	5·36
Cement	1		88·0	1·41	6·29	·233	4·9
					44·98	1·666	32·46

H	I	J		K	L	M
Percentage of Voids.	Percentage of Solids.	Absolute Volume.		Materials.	Weight in Lbs.	Specific Gravity.
Percent.	Percent.	cu. ft.	cu. yd.	Kind.	cu. ft.	
34·8	65·2	21·124	·782	Bricks	118	1·90
40·6	59·4	3·736	·138	Sandstone . . .	160	2·60
54·4	45·6	2·868	·106	Cement	193	3·10
		27·728	1·026			

It would be noted in Table III, Column J, that the sum of the absolute volumes of materials was slightly in excess by approximately ¾ of a cubic foot, and that no account had been taken of the water used in mixing. That naturally led to the next consideration.

DATA AND RESEARCH.

Theoretically, there was ·728 of a cubic foot, approximately 2·6 per cent., of solid matter in excess, without considering the volume occupied, if any, by the water used in mixing. But in practice it was reasonable to assume that not every particle of solid matter was actually used. It could only be said that the 2·6 per cent. was greater or less waste than was required by actual tests, either in the form of research or data derived from actual operations. Some waste would actually take place; hence, the estimater must know this in order to be able to estimate accurately.

As regarded water: what was the quantity required for a cubic yard of concrete? Did it vary with the temperature, and the dryness and density of the materials? Again, did the cellular construction of the materials have any effect upon the quantity of water required? All those were matters waiting investigation. Further, did an excessive amount of water weaken concrete, and, conversely, did the absence of a correct quantity diminish the strength of concrete? It was known that concrete set a conglomerate mass physically as a result of the hydration of the cement, but chemically the reason was not known. What caused the mass to set in a conglomerate whole remained as yet a mystery. It was not known whether the water combined chemically and consequently occupied no space in the mass; if, on the other hand, it retained a separate entity, then on evaporation the concrete would be honeycombed to the extent of the space occupied by the water used in mixing. Table I showed that 25 gallons of water was equal in volume to 4 cubic feet. Had that volume to be taken into account in determining the absolute volume of materials? That was a matter on which the estimater must satisfy himself before he could estimate accurately. One would think that one way of determining that was to weigh the resultant mass and compare it with the absolute volume of dry materials, deducting only the amount of water the materials would absorb in a natural way, and found by experiment. That, however, would not suffice, as it was found in practice that the materials—particularly some aggregates and sands—increased in bulk by the absorption of water. Finally, in practice, concrete when it set, shrank perceptibly. Therefore it was necessary to determine whether this shrinkage was due to a shrinkage of materials in the process of drying, or due entirely or partly to the evaporation of the water, and what proportion of water was evaporated and what proportion combined chemically, if any, with the cement.

It was important, in order to estimate accurately the price of a cubic yard of concrete, that the weight of materials loosely packed should be ascertained. That, of course, might be arrived at by a series of tests, which ought to produce an average that should suffice for all practical purposes.

Since materials were purchased by weight it behoved the estimater to determine what percentage of water the materials contained. It might be found cheaper to provide additional water in mixing rather than pay a high price for wet materials. It might be found to be even cheaper to buy none but reasonably dry—1 per cent. to 2 per cent. moisture—materials and saturate them with water before applying the cement than buying materials which contained an excessive amount of water. When the materials, such as gravel and sand, were purchased by the cubic yard the principle remained the same. Sand, when wet, was heavier and greater in bulk than dry sand of the same quantity. Wet sand was dearer in consequence, the contractor paying for the supply and carriage of water at the price of sand.

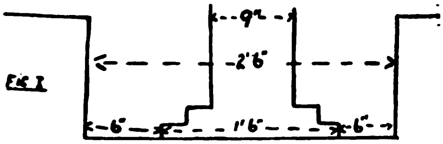
It should be remembered that the proper proportioning of concrete materials increased the strength obtainable from a given amount of cement, and also the water-tightness. Conversely, it permitted, for a given requirement of strength and water-tightness, a reduction in the amount of cement, thereby reducing the cost. For a given requirement of strength, the quality of materials might affect the cost. For example, it might require more cement for such sands that contained impurities and less cement for such sands in which impurities were absent. Impure sand might be cheaper than pure sand, but as a result of additional cement having to be used it might make the cost of concrete dearer, and consequently this must be taken into consideration when estimating. The sharpness of sand and aggregate or its absence had no effect whatever upon the setting qualities or strength of concrete.

EXCAVATION COSTS.

In pricing, the most difficult task was that of determining the labour costs. The actual amount of materials to be used, their value, and all charges upon them, might be estimated with accuracy to within reasonable limits. Not so the labour costs. The materials might be calculated by analysis, but analysis of labour costs would not help materially unless data of costings of similar works were available which were applicable to the case under review. Irrespective of this, much was based upon assumption, even in general matters, even when an analysis of both materials and labour could be made, as the following example would show:—

"EXCAVATION TO SURFACE TRENCH, 3 FT. DEEP, PART RETURNED, FILLED IN RAMMED SOLID, REMAINDER CARTED AWAY."

It was generally assumed the amount of materials returned was two-thirds that of the total excavated. It was as well to examine that assumption closely, as it would be found that only certain conditions—a certain width of trench—would give that approximately. Let us, then, assume a trench, say, 3 ft. long, of which *Fig.* 1 was a diagram.



The quantities were as follow :—

Excavation to trench :			
3.0			
2.6			
3.0	22.6		22.6
Space occupied by wall :			
3.0			
9			
3.0	6.9		
3.0			
4½			
9	0.11.3		
	7.8.3	say	7.9
		difference	14.9

Assuming that ordinary soil increased in bulk by 25 per cent. after excavation :

Thus 22.6 + 25 per cent. = 28.1
„ 7.9 + 25 „ „ = 9.8
difference 18.5

It would therefore be seen that the actual space required to be filled was approximately 14 – 9 ; but the increased bulk excavation to be returned was 18 – 5, leaving a surplus of (18.5 – 14–9) 3–8.

But it might be assumed that more than 14 – 9 of the increased bulk excavation would be returned, as it would be compressed on ramming. Then, if two-thirds of the surplus 3–8 were allowed for as being returned, i.e. 2–5, which when added to 14–9, gave a total (14–9 + 2–5) 17–2, and the difference 3–8 – 2–5) = 1–3 added to 9–8 made as total (9–8 + 1–3) = 10–11 to be carted away.

Now, 10–11 of 28–1 was slightly more than one-third, or $\frac{131}{337}$ = 0·389 approximately, so that the amount to be carted away was slightly in excess of one-third.

For practical purposes this figure might be assumed as one-third, but only when the trench was 12 in. wider than the bottom course of footings and when the bottom course of footings was double the thickness of the wall. The deeper the trench the more it approached that figure ; the shallower the trench the more excavation there was to be carted away. That was accounted for by the space occupied by the footings, which remained constant for all depths of trenches.

Hence, in pricing an item of that description, it was essential that the width as well as the depth of trench should be stated before it could be assumed that :—

Two-thirds of the excavation was returned.

One-third of the excavation was carted away.

It was assumed for the purpose that it was carted to a tip one mile distant, and the tip fee was 1*s.* per load.

Up to that point only material had been dealt with. The next consideration was that of labour, and for this, in the absence of thoroughly reliable data, several things must be assumed before the item could be priced with any hope of success.

(1) Assume that a labourer would excavate and throw into a cart and return surplus 6 to 8 cubic yards per day of 8 hours, and that his wage was 1*s.* 2½*d.* per hour. Allowing for contingencies, and accepting the lowest figure, namely, 6 cubic feet per day, then the price would be for one day :—

8 hours at 1*s.* 2½*d.* = 9*s.* 6*d.* ÷ 6 =
1*s.* 7*d.* per cu. yd.

(2) Assume that a horse and cart travelled 20 miles per day of 8 hours, which would represent 10 journeys there and back. But as there would be a certain amount of time lost in loading and unloading, say 20 per cent., therefore, 10 journeys less 20 per cent. = 8 journeys = 8 loads. Assume the cost of a horse and cart and man for one day to be £1, then the cost of one load would be :—

$$\frac{20s.}{8} = 2s.\ 6d.$$

(3) Assume that the average box-cart in the north would take about 36½ cubic feet per load, and as earth increased in bulk by about one-fourth on excavation, therefore a cubic yard of excavation after allowing for its increased bulk would be 3–39, which was slightly less than what a box-cart would hold by 2–9 cubic feet. But it might be assumed that a cart would not always be filled to the full capacity, and therefore it might be assumed that it would take away, say, one cubic yard per load.

Hence the net cost of a cubic yard of excavation would be :—

	s.	*d.*
Labourer	1	7
Cartage, ¼ of a load	0	10
Tip fee, ¼ of a load	0	4
	2	9

To which must be added overhead charges, insurances, workmen's compensation and profit, thus :—

	per cent.
Overhead charges, plant, say	4
Health, unemployment and third-party risk, say	2½
Workmen's compensation, say	2
Profit	10
	18½

Therefore, 2*s.* 9*d.* + 18½ per cent. = 2*s.* 9*d.* + 6·10*d.* = approximately 3*s.* 3*d.* per cu. yd.

SUMMARY.

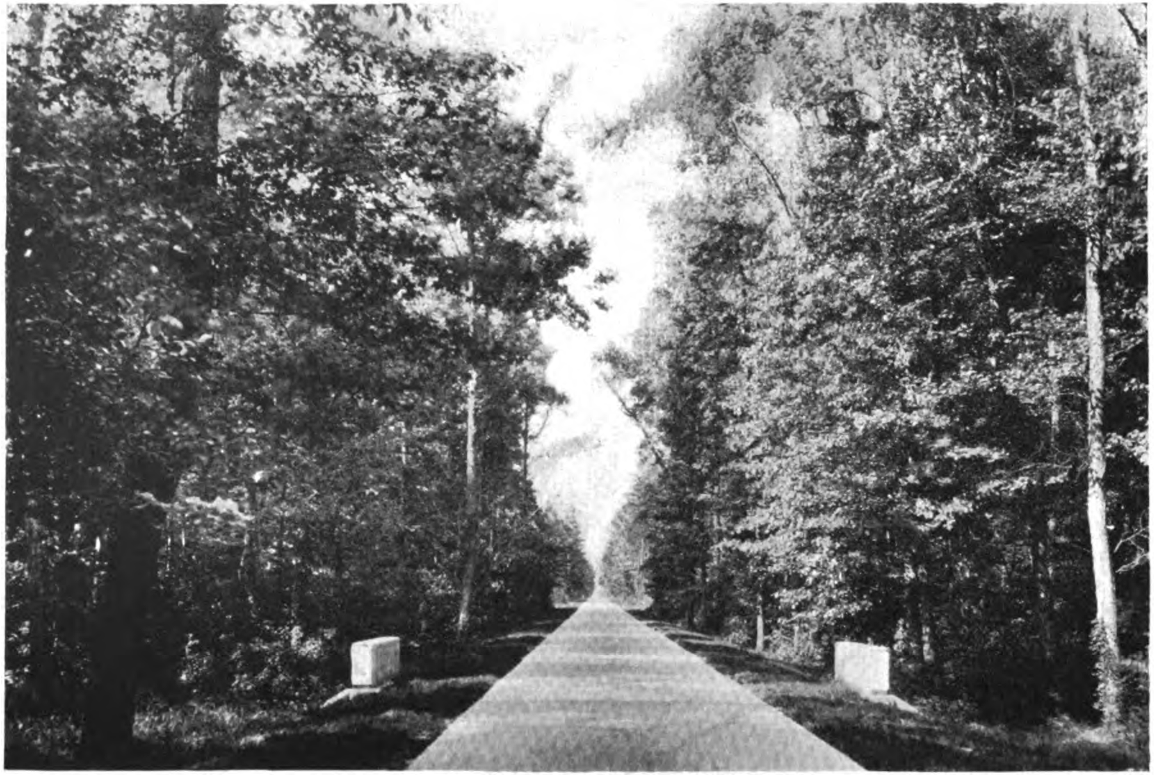
Summarising, the principles of estimating necessitated the splitting up of an item into its component parts, and each unit treated separately for costs, which should be in relation to its component parts where they were affected by relation thereto. Taking the illustration of excavation as an example, the percentage to be added for plant must be considered in relation to the class of work, as it was obvious that were the item a piece of joinery work the cost of plant would be greater than 4 per cent.

Owing to the present method of measurements materials were mixed up with labour, with certain exceptions, notably stonework. That complicated matters and rendered it difficult for the installation of a scientific system of investigation—by costing or other means—for arriving at the cost of the respective units or the component parts of an item. When such had been ascertained the data might be rendered useless by a fluctuation in cost of any one of its component parts. For instance, why should not excavation be considered apart from filling-in, and these quite apart from carting away, tip fees, overhead charges and profit ?

Unfortunately, since the price of an item of many parts had to be considered, it was necessary to base prices mainly upon assumptions, but that was even more reliable than lumping or guessing the price ; or because it was known that "so-and-so's price for such an item is 10*s.* and we must ' cut it ' by one penny to ' get the job,' whether we can do it at 9*s.* 11*d.* or not." Would it not be more sensible to see whether it could be done for 9*s.*, and if it could let that be the price ; then the bogey of competition would be non-existent.

It was impossible in a short paper to deal with the subject exhaustively and conclusively. Take the case of a cubic yard of concrete—he had only touched upon the fringe of that item. Was it right to specify concrete by the proportions of its parts ? Should not the materials be specified by their specific gravity ? How should an item be priced which gave broken bricks or stone or other like materials to approval ? Bulk for bulk the price might vary considerably, likewise the cost of carriage or haulage. Again, was it certain that the proportions sometimes specified would produce an absolute volume of concrete ? Aggregate and its sizes must be in proportion to its matrix. For example, would, say, proportions 7 : 1 : 1, in which the sizes of aggregate were not less than 2 in., produce a solid volume of concrete ? And, if not, and since a solid volume of concrete must be produced, how would the cost compare with the estimate ?

A scientific study of pricing, seeing that it must of necessity take into consideration a review of the whole field of operations, might ultimately lead to a reduction in costs, whilst at the same time it might not only assume profits but benefit the country in general by a reduction in the cost of building and engineering works, and guarantee better wages. Concrete was now used in building and engineering works beyond the dreams of those of 30 years ago, but it was as yet only in its initial stages. The study of the uses of concrete and its costs might effect many savings.

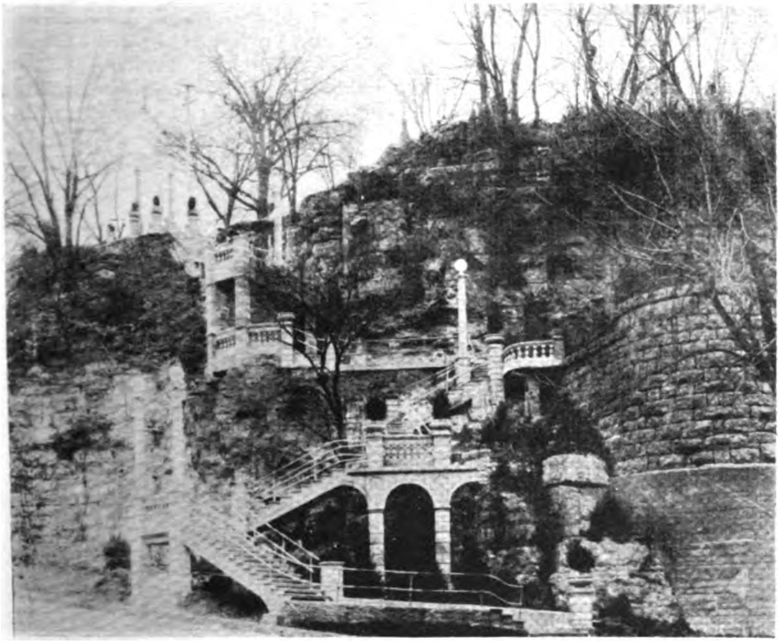


A CONCRETE ROAD OVER A UNITED STATES SWAMP.

[This Photograph shows part of the ten miles of Concrete Road over the Elendale Swamp, Delaware.]

CONCRETE PARK STAIRWAY.

In order to replace an old frame structure serving as a stairway, the city of Dubuque, Iowa, has constructed a concrete stairway from one of the city parks to the boulevard level below. Advantage was taken of the various ledges of rock along the cliff face to break the monotony of a straight up and down climb by forming landings which change the direction of travel. As well as changing the course of the pedestrian the landings enable pedestrians to stop to enjoy the views obtainable over the Mississippi River valley.



Concrete Stairway at Dubuque, Iowa.

The total length of the stairway, which is entirely of concrete, is 200 ft., while the height is 85 ft. The steps are 5 ft. in width and 6 in. in height with a 12-in. tread. In all there are 150 steps in the stairway, with six landings. A feature of the stairway is the night illumination. Pillars carrying electric globes are situated at intervals so as to allow a good lighting in all directions.

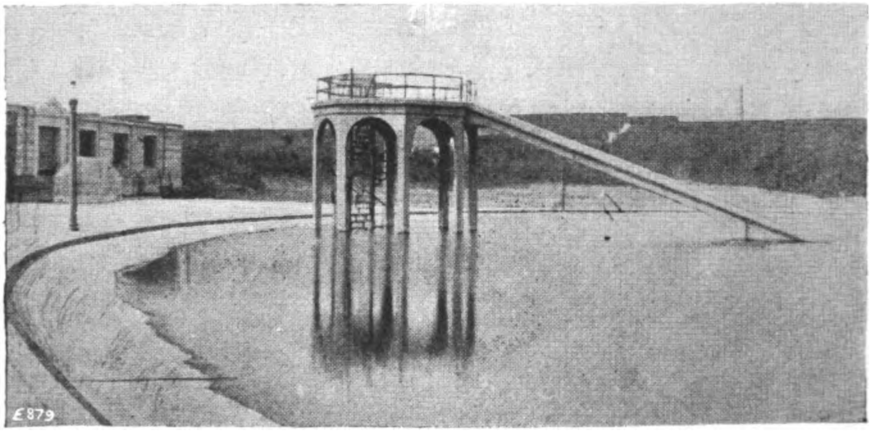
EFFECT OF TEMPERATURE ON THE FORMATION OF CALCIUM SULPHO-ALUMINATES.

It has long been known that the expansion and cracking caused by the addition of gypsum to Portland cement rapidly diminishes when pats of the cement are maintained at temperatures above 40° C., and does not occur at all at 100° C., so that either calcium sulpho-aluminate is not formed above 40° C. or its solubility increases so rapidly with a rise in temperature as to prevent it doing any harm at the high temperatures.

As Michaelis has shown that the salt can be crystallised from hot solutions (though with difficulty) it would appear that the reduction in expansion at high temperatures must be due to the increased solubility of the salt. To ascertain exactly what occurs, H. Kuhl and H. Albert prepared pure calcium sulpho-aluminate at various temperatures by adding lime-water to a solution of aluminium sulphate in proportions corresponding to the calcium sulpho-aluminate ($3CaO.Al_2O_3 + 3CaOSO_4$) and maintained the mixed solution at these temperatures for varying periods up to 28 days. They found that below 20° C. the mixed solution is at first clear, but rapidly becomes turbid with formation of a flocculent precipitate which is seen under the microscope to be composed of minute needles of the required salt. At 40–60° C. a slight turbidity due to precipitated alumina occurs, but this is rapidly masked by the abundant formation of crystalline needles. At 80–100° C. the lime-water was slightly turbid on account of the lesser solubility of lime in hot water. On mixing the hotter solutions a considerable time elapsed before any marked signs of reaction occurred, and even after several days the only crystals obtained were hexagonal tables of calcium hydroxide, scarcely any needles appearing.

Analyses of the precipitates formed at various temperatures showed that their composition is constant below 40° C., but above this temperature the crystals contain an excess of free lime, though this constituent is not constant in proportion, but varies irregularly, implying that at the higher temperatures crystals of free calcium hydroxide are formed and are mixed with any sulpho-aluminate crystals which may be present.

It thus appears to be definitely proved that the absence of expansion of cement pats when kept in hot water is due to the calcium sulpho-aluminate being soluble and harmless, though it rapidly crystallises out at temperatures below 40° C., and may then cause damage.—*Zement.*



Concrete Swimming Pool in a Public Park: The Platform and Chute are also of Concrete.

CONCRETE PRODUCTS.

In view of the increasing demand for pre-cast concrete goods, and of the size to which the concrete products industry has now grown, we propose in future to give more space in each issue to developments in the manufacture and uses of these articles. Descriptions and illustrations of new concrete products or new applications of concrete, for publication in this section, will be welcomed.

PRE-CAST concrete goods can be divided into three classes :—

(1) For use under the ground ;
(2) For use on the ground ; and
(3) For use above ground.

In the first category, concrete pipes have now been in use for over twenty-five years, and their strength, uniformity of manufacture, and low price all go to make an ever-increasing demand. They are made in all sizes both reinforced and unreinforced, generally in 3 ft. lengths. The standard thickness is one-twelfth of the diameter, e.g., a 24 in. pipe is 2 in. thick and a 36 in. pipe 3 in. thick. A large number of tests on concrete pipes have been carried out by various engineers with satisfactory results, and recently several 30 in. pipes were tested when placed between two flat surfaces and the average pressure was nearly 3 tons to a 3 ft. length. Another interesting test was made by a Rural District Surveyor ; 18 in. pipes were used to fill up a ditch on the side of the road, taking care that the pipes were laid on a good flat surface and well haunched with concrete at the sides and with a covering of only six inches of road material, and these pipes have withstood a traction-engine passing over them longitudinally without any fracture whatever. Tests for absorption have also been often carried out, and show that it is practically *nil*.

It costs less to lay concrete pipes because generally there are no sockets, thus saving extra excavating, and considerably less material is required for each joint.

The next important articles for use underground are concrete manholes. Here, again, a very great saving is shown over brickwork, not only in the initial cost but in efficiency, and there can be no question of leakage in concrete manholes.

It is generally admitted that the right shape for the chamber of a manhole is oblong, and it is not necessary for it to be more than 3 ft. in width. Concrete manholes are now on the market with chambers varying in sizes from 3 ft. 6 in. by 3 ft. 6 in. wide rising by 6 in. increments to 6 ft. by 3 ft. wide, the size most in demand probably being 4 ft. 6 in. by 3 ft. The shaft is made in 3-ft. lengths and with 30 in. internal diameter, both shaft and chamber being fitted with galvanised tread irons.

The second category — concrete goods used on the ground — chiefly consists of kerb and

CAST STONE BRACKET.
Designed by PROFESSOR C. H. REILLY, F.R.I.B.A.
(*See* p. 116.)

CONCRETE FENCING.

Fig. 1.—Raised Panel Fence.

Fig. 2.—Cast Stone Balustrading.

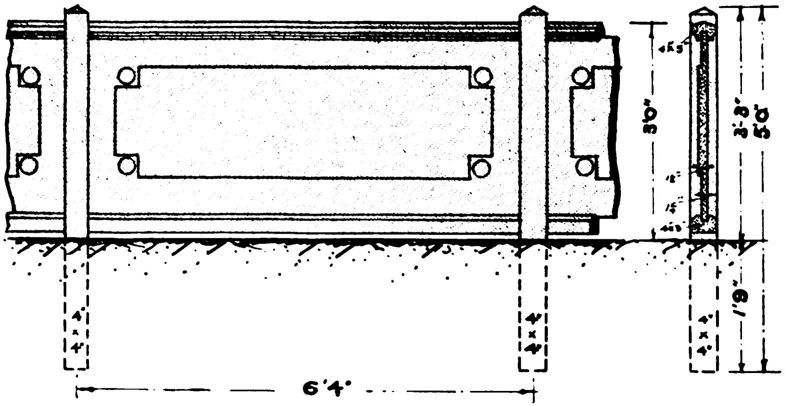


Fig. 1.

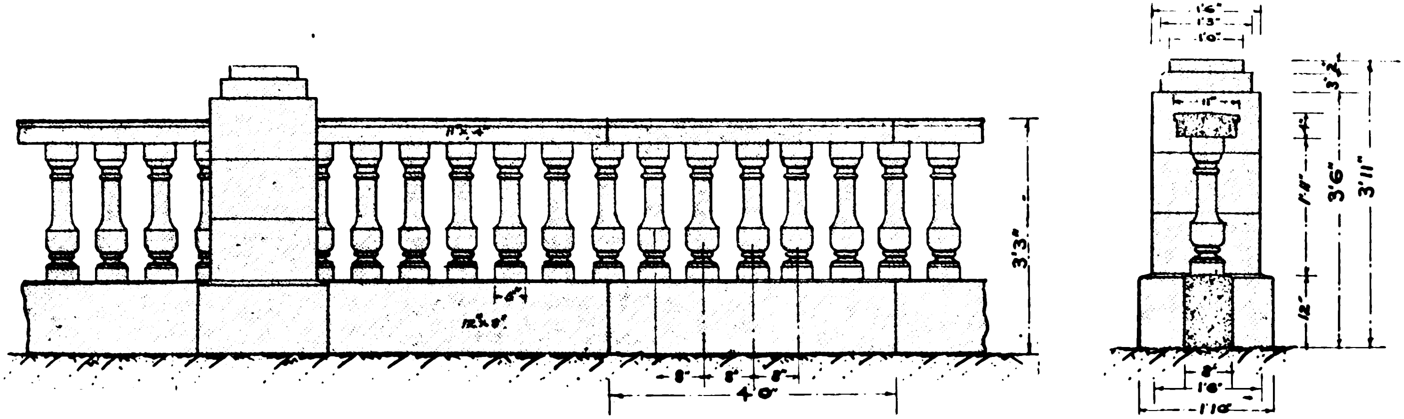


Fig. 2.

channels and paving slabs. The former, especially the kerb, is being used by a great number of local authorities on the new roads and widenings of roads, particularly on all concrete roads and on roads constructed of other materials where there is a ditch at the side and something is required to prevent the bitumen from creeping. Such kerbing may either be bought in 3 ft. lengths ready made, or made *in situ*. Concrete kerb is generally made 9 in., 10 in. and 12 in. by 3 in. thick, rising in inches to 8 in. Concrete paving slabs are so well known and generally used that it is not necessary to go into the matter of their utility; they are generally made 2 in. and 2½ in. thick.

Concrete goods for use above ground level chiefly consist of concrete posts of every description. Providing the posts are made properly with the correct proportions of aggregate and care taken that the reinforcement is in the right position, a concrete post is practically everlasting, and moreover concrete posts with wire make a most economical fence. Railway companies have fully grasped this fact, as is evident to anyone who travels by train. A fence with 8 wires, the posts 9 ft. apart, complete with end posts, straining posts, and struts can be bought for 2*s.* 2*d.* per lineal yard.

Many kinds of fence posts are made, such as posts for tubular fencing, posts for chestnut fencing, for close-boarded fencing made ready to take the arris rails, and posts for clothes' lines—how many times in a few years does one have to renew these necessary domestic articles when they are of wood? Although fencing posts are mostly in demand, such posts as telegraph poles, signal posts, cable posts, road direction posts, motor sign posts, lamp posts, etc., are being extensively used, and their demand is continually on the increase.

Concrete garden rollers are not new, but they meet with a big demand, being cheap and everlasting.

A new use for concrete has been found in the ends for garden seats; the battens for the seats are fastened with wedges and are easily removed, so that the seats can be stored for the winter in a very little space.

The use of concrete units for building construction, such as blocks, slabs, lintels, door-hoods, roofing tiles, ornamental features, etc., covers a very large field, and we hope to illustrate and describe a number of such applications in this section. A large concrete-block garage recently completed at Palmers Green is illustrated in this issue.

CONCRETE FENCING.

A great variety of pre-cast concrete articles, including all those enumerated above, are made by Messrs. Manufactured Concrete Works, Ltd., of Barnstaple, North Devon, and 39, Victoria Street, S.W.1, a concern started by the British Construction Company for this class of work, some of whose fencing is illustrated in *Figs.* 1 to 3. *Fig.* 1 shows a raised panel fence which should be suitable for a great variety of purposes. A cast stone balustrading is illustrated in *Fig.* 2. The balusters are 5 in. square and 1 ft. 11 in. high; the handrail is 11 in. by 4 in., and is made in 4-ft. lengths, and the bases are made in the same length but 12 in. by 8 in. in section. The piers are placed where required, either to strengthen the balustrading or for effect.

The method adopted by this firm of attaching woven wire fencing to reinforced concrete posts is shown in *Fig.* 3

A device for protecting the edges of concrete kerbs from damage from the

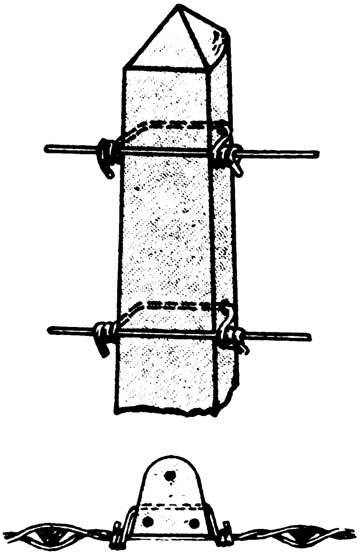


Fig. 3.—Method of Attaching Woven Wire Fencing to Reinforced Concrete Posts.

wheels of passing traffic is illustrated in *Fig.* 4. This takes the form of a steel kerb edge, consisting of steel angle with lugs attached to fix securely into the concrete. The protection is supplied in sizes to suit any kerb, and it can be bent to any shape for curves, etc. The lugs are attached alternately on the top and side of the edging, this ensuring a firm hold throughout its length. We are informed that nine miles of this kerb protection was recently laid for the Godstone Rural District Council at a cost which added very little to the total cost of the kerb.

CAST-STONE BRACKET.

On p. 113 we illustrate a particularly good specimen of cast-stone work in the form of a bracket made by the Concrete Unit Co., Ltd., of Trafford Park, Manchester, to the design of Professor C. H. Reilly, F.R.I.B.A. (Professor of Architecture at Liverpool University). The manufacturers are to be congratulated on the cleanness with which the concrete has been moulded; when placed in position on a building it would be quite impossible to distinguish such moulded work from stone which had been carved by hand at a considerably greater cost. The fact that the work was designed by Professor Reilly is an indication that architects are taking an increasing interest in newer methods which give **results quite as good as the old, while at the same time decreasing the cost, which is undoubtedly the chief factor responsible for so much building work now being held up.**

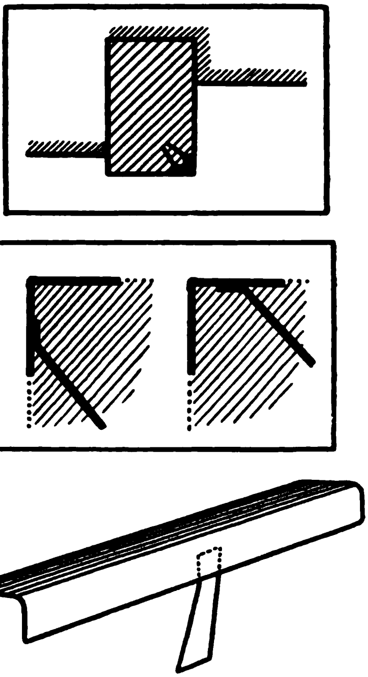


Fig. 4.—Steel Protection for Concrete Kerbs.

Concrete Cottages for Merthyr, Birmingham and Southend.

The very important point that concrete cottage construction does not require the services of the skilled building operative, and that work carried out in this material will not be held up for want of labour as is so frequently the case with brickwork, is now generally realised.

The Merthyr Corporation has adopted a recommendation of its Housing Committee to the effect that 150 new cottages be erected in concrete by local workers, who can be sufficiently trained to carry out concrete cottage work in a very short space of time.

Two tenders have been accepted by the Birmingham Public Works Committee for the erection of 1,500 concrete houses.

The Southend-on-Sea Town Council has accepted a tender for the erection of 66 concrete houses on the Sutton Road site, at a cost of £26,208.

Concrete Paving.

The Tavistock Urban District Council has decided to pave several footpaths in the town with concrete slabs.

A DIRECTOR OF HOUSING ON CONCRETE COTTAGES.

THE SUPPLY OF LABOUR.

IN a report presented to the Edinburgh Town Council in connection with its proposal to erect 1,000 cottages, Mr. A. Horsburgh Campbell, the Director of Housing, states :—

"The experience of housing administration within the city in recent months had shown the futility of relying further or longer upon the supply of bricks, and equally so upon dependence on the bricklayer; except under conditions which the Committee had not been able to adopt. But beyond and apart from any such conditions was the great and growing shortage of brick supplies and almost equally the shortage of plasterers.

"These hindrances to housing progress, which were not merely local, but were, in the main, national, called for the initiation of new means and methods to supply the end in view; that is, the provision of houses of two and of three apartments, to the number of at least 1,500 in the next eighteen months.

"He had been considering, along with the Convener of Committee, how this threatened paralysis of housing progress could best be averted. To that end, he had been making inquiries, both local and further afield, as to the possibility of obtaining proposals from building firms for the erection of houses composed of materials other than brick. He referred, for instance, to concrete and to timber, also to steel-frame structures. Concrete, either in block or slab form, concrete *in situ*, and other such forms of application were available as substitutes for and auxiliaries to stone and to brick—with the added merit, considered in relation to present-day conditions, that the use of concrete in either block, slab, or *in situ* form, would mean the providing of local work for local unskilled and unemployed labour, which was itself a great advantage.

"Such houses, erected in one, two, or even of three stories high, were as substantial as houses built in brick. The city's recent experience with the concrete houses at Wardie was a local demonstration in proof of that point. But with all past experience of local difficulties and with the need for houses more clamant than ever, it was now time to launch out upon a scale more nearly commensurate with the needs."

CONCRETE PRODUCTS AND HOUSING SCHEMES.

AMONG the news given under the heading, "Prospective New Concrete Work" in this issue there will be found much to interest manufacturers of concrete products. There should always be a market for concrete blocks, partition slabs, lintels, door hoods, and ornamental features in concrete or cast stone whether the walling of the houses is to be built of concrete or any other material, and at the present time there is considerable activity in the housing schemes of local authorities.

At Weetslade the Urban District Council proposes to erect 300 cottages; the Barnstaple Town Council has applied for a loan for the erection of 100 houses; the Clowne Rural District Council proposes to build 30 houses; the Colchester Town Council has applied for a loan for the erection of 32 houses; the Epsom Rural District Council proposes to build 300 houses; a scheme for slum clearance is in hand at Liverpool; the Llandovery Town Council is to build 50 houses; a sum of £23,000 has been applied for by the St. Pancras Borough Council for housing purposes; 300 houses are to be erected by the Stockport Corporation; 300 houses have been sanctioned by the Ministry of Health for erection by the Torquay Town Council; and 40 houses are to be erected by the Wellingborough.

All these schemes should provide openings for the sale of concrete products, if the economies which the use of concrete makes possible is demonstrated to the local authorities responsible for the work.

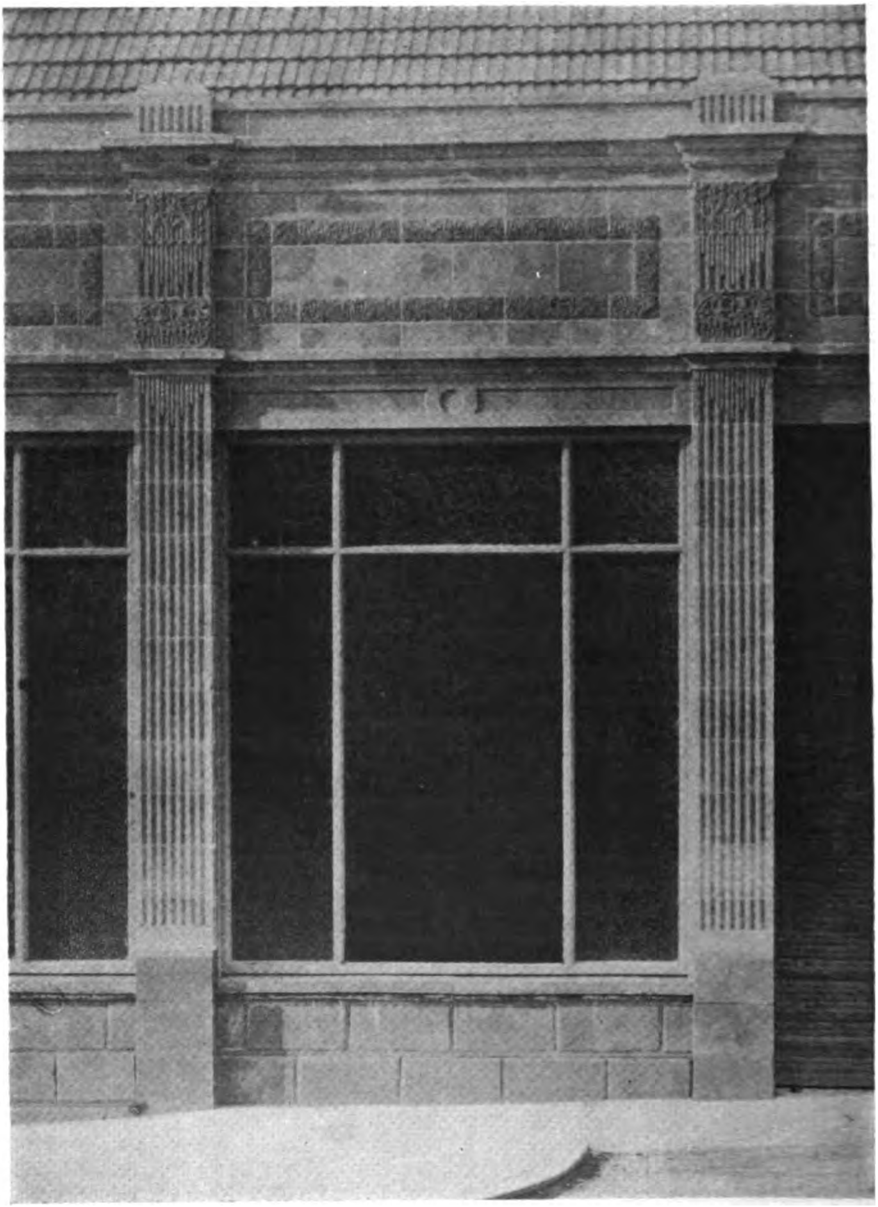


Fig. 1.—WINDOW PANEL OF CONCRETE BLOCKS AT GARAGE AT PALMERS GREEN. (*See p.* 119.)

A CONCRETE-BLOCK GARAGE.

An example of concrete block and unit construction in this country is the building illustrated herewith, known as The Central Garages, recently erected at Hedge Lane, Palmers Green, for Mr. J. J. Gates.

The main roof covers a total area of 9,000 sq. ft., which is divided into a workshop, showrooms, offices, and 16 car lock-ups. At the rear of this main building are an additional 55 concrete lock-ups previously erected, which were so satisfactory that the proprietor decided in favour of using concrete units for the larger building. These units range from plain 3 in. cinder-breeze partition blocks to the ornamental moulded work of the pilasters, lintels, and cornices. Being a question of economy of cost as against ordinary brickwork, and of utility rather than appearance, there could be no attempt at cast stone, set carefully to ⅛ in. or less joints, and frankly moulded concrete, either as plain block or ornamental casting, was therefore adopted, and the architect, Mr. Chas. A. Marques (consulting architect to the block makers, Messrs. Concrete Manufacturers (No. 1, London), Ltd., of Brimsdown, Middlesex), designed the building accordingly.

Being intended in the near future to receive an additional story with concrete flooring, the architect made use of the reinforced system of concrete block walling patented by the Company's Managing Director in 1919, shown in *Fig.* 3. This construction consists of units of **E**, **F**, **L**, **T**, and **U** shapes, built around the reinforcements, and filled with a bearing area of concrete as the work proceeds, usually and preferably by filling in to half-course height, so that the mass of poured concrete breaks joint with the block unit; this prevents undue lateral thrust to the last-built block. Piers may be constructed within the cavities of the "**T**" walling, or pilasters formed as required.

The partitions between lock-ups, etc., being of small extent, are 3 in. in thickness, all built to three courses of stone concrete, all courses 12 in. high, and above that of good breeze concrete. These are illustrated in the constructional views *Figs.* 4 and 5, where it will be noted that the walling is bonded to reinforced piers. These piers carry the concrete girders cast *in situ*, which are intended to support the superimposed load when the other story is erected. The whole of the pier casings as well as all external blockwork and main walling is of good quality stone concrete left

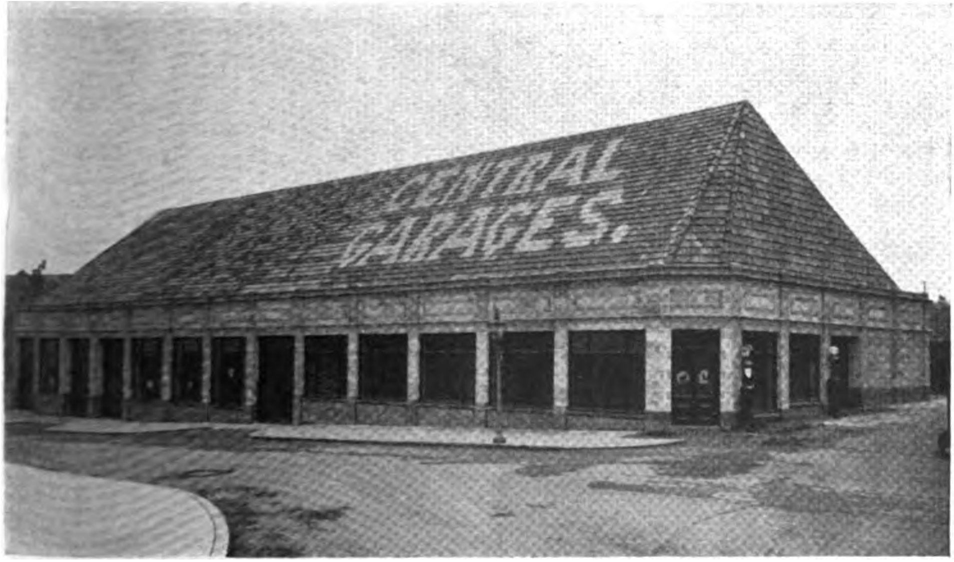


Fig. 2.—Concrete Block Garage at Palmers Green.

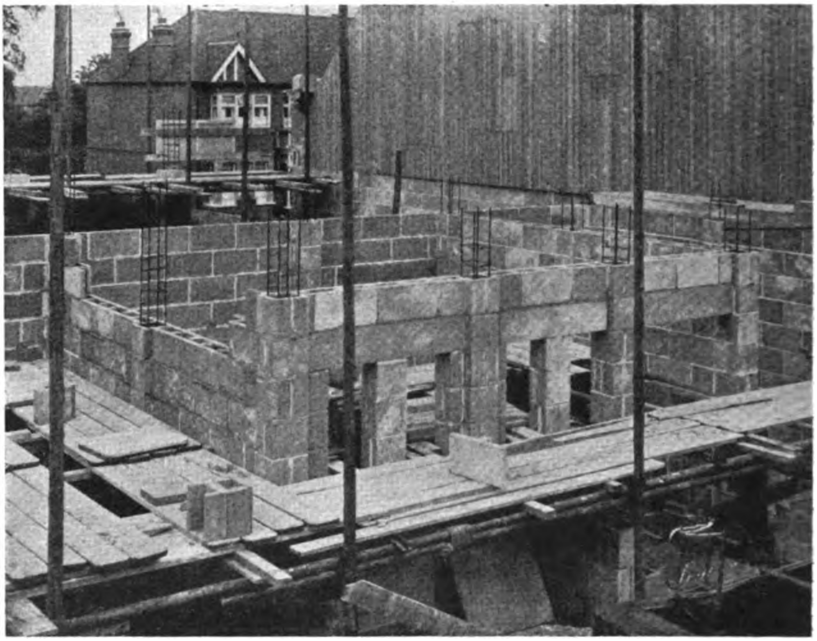


FIG. 4.—SHOWING WALL CONSTRUCTION AND STEEL PUTLOGS.

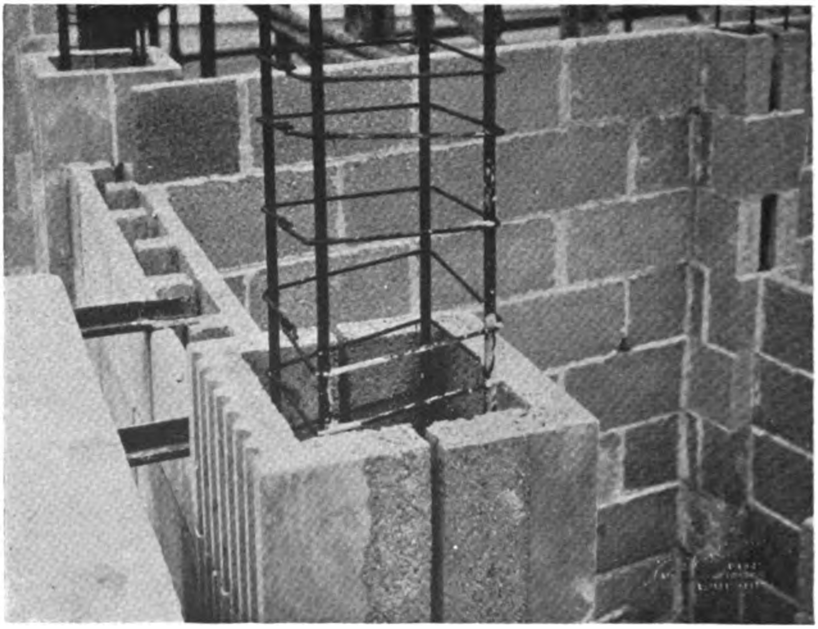


FIG. 5.—SHOWING CONSTRUCTION OF WALLING.

CONCRETE BLOCK GARAGE AT PALMERS GREEN.

rough or faced with fine finish and colourings, according to position.

All concrete units are steam cured, and of a mix that is gauged to render all weather-resisting parts absolutely impervious, and stressed units fully capable of sustaining their loads. As a result of their experience of this class of work, the block-makers use a water percentage to the mix which is recognised as giving the best results, while the facings are gauged to equal the expansions and contractions of the mass, so that crazing from inequalities of this kind is entirely obviated. This Company has also found that when not of equal and fine mix throughout, the body should be of slightly richer matrix than the facings, especially when projecting as mouldings, etc.

The building stands upon a site which has a fall of 6 ft. from corner to corner diagonally; also the foundation soil was so varied in bearing value that footings were rarely duplicated, either being carried down to firmer bearings or spread to gain capacity; *Fig.* 2 gives an idea of the fall. The floor inside is in two levels, the higher end being 3 ft. above the level of the lower. For convenience of storage, etc., the lower end of the building (the first eight panels) was completely finished before proceeding with the remainder. *Fig.* 1 is a window panel between two of the doors, and sufficiently discloses the fluting, reeding, and other ornament cast in the blocks forming the piers, as well as the panelling of the lintels and frieze. The lower portion of the façade is of mottled red and black facings, cast with the block, the sills being treated in the same manner. The upper portion is of a general pale buff appearance, being actually a mottling of two buff facings, light and dark, cast haphazard. The lintels over doors and windows, cast at the Company's works, are reinforced for all anticipated loads, and are in two parts, the outer one conforming to the exterior facings and the inner to the plain cement facings of the interior. Making these in two parts permitted of cast-down facings on both exposed faces, and gave convenience of handling.

Figs. 4 and 5 are taken from the roofs of the rear lock-ups. *Fig.* 5 also shows the steel putlogs used in the construction.

When supplying material of this kind

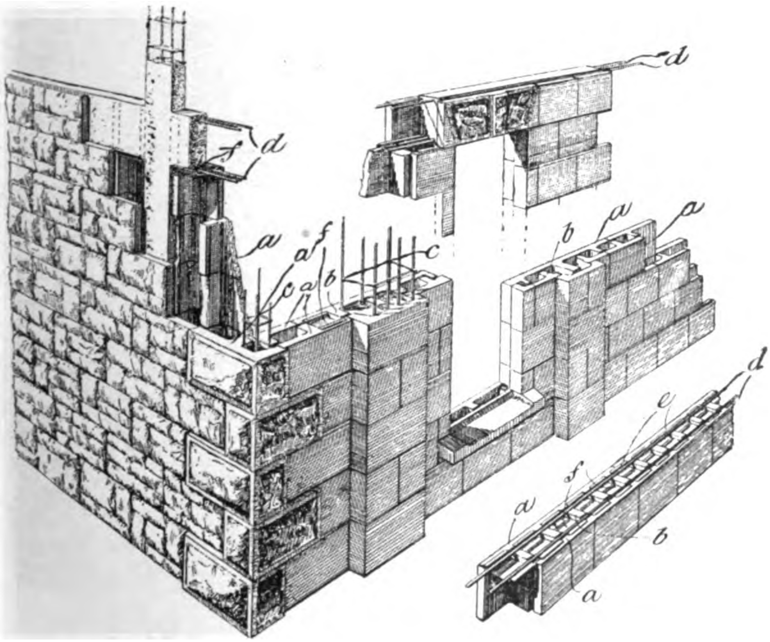


FIG. 3.—SHOWING TYPE OF CONCRETE BLOCK WALLING USED AT THE GARAGE AT PALMERS GREEN.

the Company provides a complete set of detail drawings which show every block in elevation and all variations in plan ; *Fig.* 6 is part of a sheet showing details of the front elevation. No block of ordinary size and shape is figured in the drawings, but all shorts and odd shapes and sizes are marked in dimension, and supplied accordingly.

Fig. 2 illustrates the expanse of roofing, which is probably one of the largest concrete tile roofs in the kingdom. The name picked out in white tiles contrasts vividly with the rich red of the general tiling, and is placed at one end to form a complete sign centering to a vista seen at some considerable distance. The steep pitch was designed to contain, when

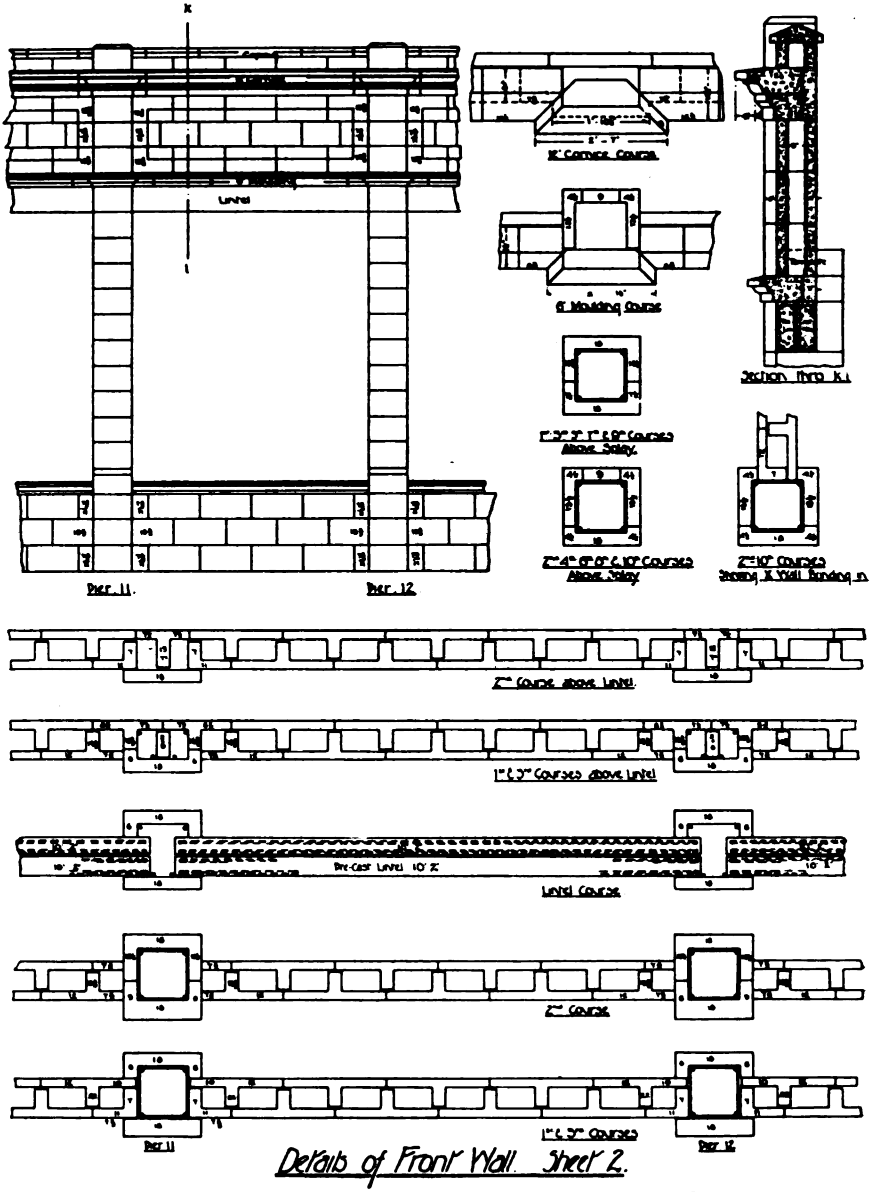


Fig. 6.—Concrete-Block Garage at Palmers Green : Details of Front Elevation.

re-used over the second story, a ceiling which will arch high into the space between the levels of plates and ties, and with the intended story and higher parapet will be less prominent. The tiles used are of the "reform" pattern with storm heads and double side locks which permit of very small lap both ways. Every fourth tile has a galvanised wire, cast in, which may be attached to the battens. There are only 130 tiles to the square, which weighs 700 lbs., or about half the weight of the usual clay tiling. The half-round ridging is also of coloured concrete.

The roof principals, footing upon reinforced concrete templates and spanning 50 ft., are of steel angles and tees, constructed and erected by Messrs. Lambourne & Co., Ltd., of 64 Victoria St., S.W.1. These carry the timber purlins which in turn support the rafters, battens, and tiles.

The whole of the walling and other concrete work, including floors and several large girders cast *in situ* to hold machinery, was done by direct labour employed by the owner, adhering exactly to the specifications. Stress calculations, etc., were the work of the architect.

The cost compares favourably with other adequate methods of construction, while in appearance the whole structure is comparable with, though not an imitation of, cut stone. The architect's idea was to convey, by bold jointing, the sense of units assembled into an harmonious entirety.

TENDERS ACCEPTED FOR CONCRETE PRODUCTS.

LEEDS.—*Concrete Pipes.*—The T.C. has accepted the tenders of Messrs. Cochrane & Co., Ltd., for the supply of 250 9-in. concrete-lined pipes, at £3 14*s.* 9*d.* per pipe, and 400 18-in. concrete-lined pipes, at £8 7*s.* per pipe; and of the Stanton Ironworks Co., Ltd., of Stanton Ironworks, Stanton, near Nottingham, for the supply of 340 12-in. concrete-lined pipes, at £9 18*s.* 6*d.* per ton.

LONDON (LEWISHAM).—*Paving.*—The B.C. has accepted the tender of the Atlas Stone Co., Ltd., for the supply of 2-in. artificial stone paving, at 5*s.* 11*d.* per super yd.

STAFFORD.—*Pipes.*—The T.C. has accepted the tender of Messrs. G. Sandy & Son, Stafford, at £865 2*s.* 4*d.*, for the supply of 650 yds. of 21-in. diameter reinforced concrete pipe sewer.

CORRESPONDENCE.

REINFORCED CONCRETE PIPES FOR INTERNAL PRESSURE.

SIR,—In the November and December, 1923, issues of "Concrete and Constructional Engineering" there is an article on "Reinforced Concrete Pipes" by Dr. F. Emperger on which the following criticism is submitted.

(1) It seems very unwise to attempt to calculate ultimate strengths in such composite structures, and the resultant manipulation of the modular ratio (m) is very much to be deprecated. After all (m) is more or less constant within the elastic range, and it would appear to be quite obvious that outside this range (m) can have any value, even up to ∞. Also the stress distribution in the pipe is so entirely dissimilar to that in the beam that deduction from one to the other is unsound. Would it not be simpler and more satisfactory to decide on a safe working stress in the concrete and then design so that that stress is not exceeded? The ultimate load on test will then give the actual factor of safety.

(2) Pipes such as those indicated cannot really be treated seriously as "thin" cylinders. One of the examples cited has an internal diameter of 28 in. and an external diameter of 48 in.! This pipe is rated to stand 140 lbs. per sq. in. internal pressure, and under this load the hoop stresses are 235 and 111 lbs. per sq. in. respectively at the internal and external radii on the assumption that (m) is 15, Poisson's Ratio 0·2, and that there is no longitudinal stress. The stress calculated on the "thin" cylinder basis would be 146 lbs. per sq. in. Surely these figures are sufficient to show that the "thin" cylinder calculations are quite erroneous and at the same time extremely dangerous. To design exactly is somewhat complex, but in view of these figures it should be done.

W. D. WOMERSLEY.

Cambridge.

NEW TYPE OF FLOOR CONSTRUCTION.

THE "Hollocast" hollow concrete floor, illustrated herewith, has been designed and patented by the Indented Bar and Concrete Engineering Co., Ltd. This floor consists of a series of pre-cast units in the form of hollow beams which are made of the length necessary to span between the floor supports. They are 12 in. wide and can be constructed of any depth necessary, the usual depth for ordinary loading, for spans up to about 14 ft., being 5 in. or 6 in.

The beams are constructed of reinforced concrete with a permanent metal core. The volume of the cavity is from 30 per cent. to 60 per cent. of that of the floor, and the units are so constructed that these cavities can be used to form ducts for gas tubing, electric wiring, ventilation, etc. The sides of the units are sloped inwards towards the top, and after they have been placed in position the narrow channels formed between the beams are grouted up and the final floor surface applied. In the case of buildings constructed over a series of bays, continuity bars can be inserted in the channels formed between the units, so that when the grouting has been applied the floor is to all intents and purposes monolithic over the whole area.

The units can be made on the site of the building for which they are intended, or, if this is impossible, on the nearest vacant space, thus practically eliminating transport charges and the possibility of damage during transit. They should be allowed to mature for about 7 to 10 days, but after the expiration of that period can be hoisted in position and immediately put into use. No special care is necessary in lifting the beams, unless their length is abnormal. In the case of buildings on restricted sites it is often possible to cast the beams necessary for the first suspended floor on the ground in the basement, and the beams for the succeeding floors can then be cast on the floor immediately below as soon as the latter has been placed in position and, if neces-

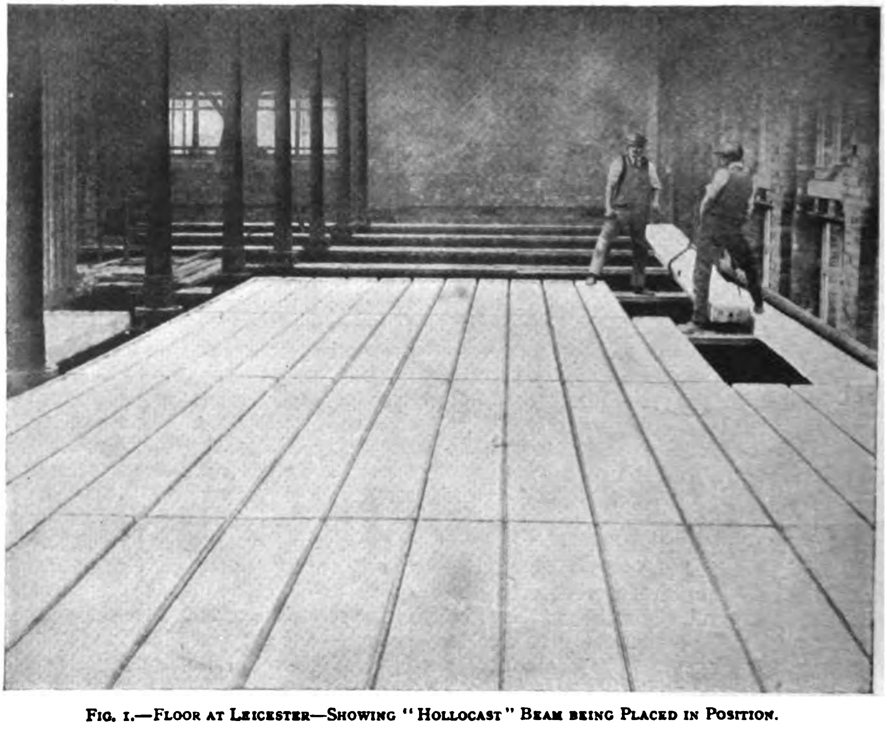


FIG. 1.—FLOOR AT LEICESTER—SHOWING "HOLLOCAST" BEAM BEING PLACED IN POSITION.

sary, before it is grouted, so that once the floor construction has been started the use of the "Hollocast" floor will expedite its completion. No support of any kind is necessary during the erection of the floor.

The floors offer high resistance to fire and changes of temperature, and are practically sound-proof. They are very considerably lighter than the majority of other floors, and thus the whole of the framework of the building and the foundation work can be lightened. The undersides of the units can be left rough to form a key for plaster work, or smooth so that a presentable flat ceiling is formed with nothing more troublesome than a coat of whitewash.

If the floor is required to be cut after it has been completed, all that is necessary is to remove the surface finish of the floor, cut out the grouting and take out the necessary number of units, afterwards trimming the opening to the required size. The untouched portion of the floor remains as strong as before.

A recently completed contract is illustrated in *Figs.* 1 and 2, during construction. On the right-hand side of *Fig.* 1, a beam can be seen being swung into position, from which the ease of handling is apparent. In connection with this contract a series of tests to destruction was made on the beams, the average results of which are as follow. The total live load for which one of the test units was designed was 18 cwts., and under a load of over 6 tons the beam still remained intact, although there was a very considerable deflection. The beam sheared under a load of just over 6 tons, so that the factor of safety was about 6·66. Up to the designed working load the deflection was too small to be measured, and the beam returned to its original form immediately this load was removed.

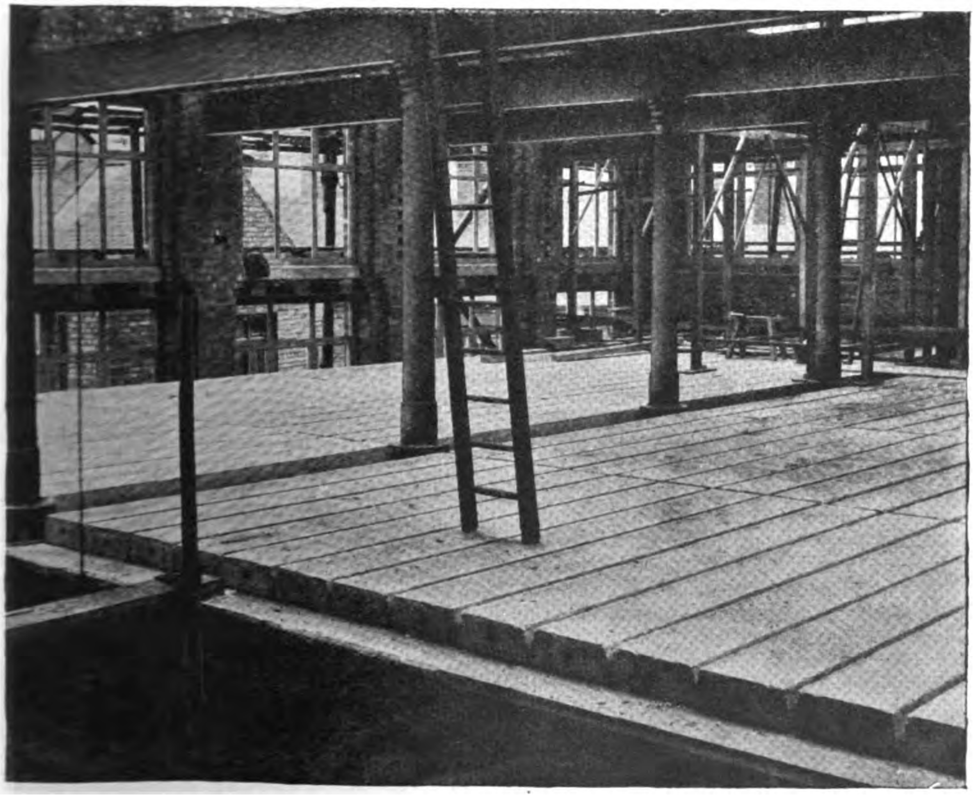
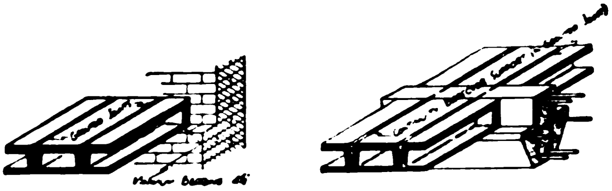
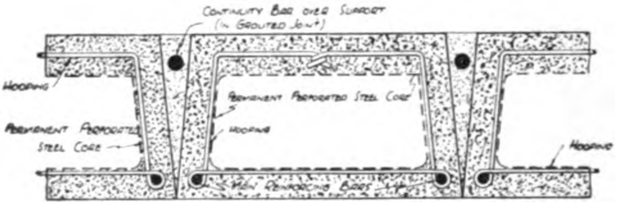


FIG. 2.—FLOOR AT LEICESTER—"HOLLOCAST" UNITS IN POSITION, BEFORE GROUTING.

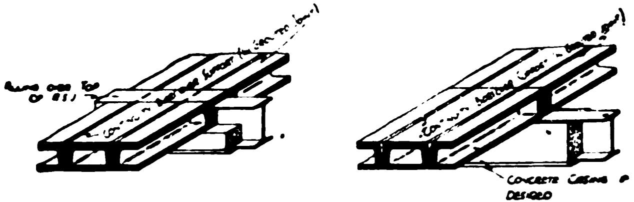


Bearing on Wall

Bearing on R C Beam



Cross Section of Floor Beam



Alternative Bearing on RSJ

Fig. 3.—Sections of "Hollocast" Floors.

When four times the designed load had been applied the deflection was less than 0·006 of the span. In one of the tests, a beam was loaded to 7 tons without failure, but the load then became unwieldy and had to be removed. In all cases the tested beams were constructed in accordance with ordinary working conditions; the concrete was mixed in the proportions of 4 : 2 : 1, and the reinforcement consisted of two ½-in. bars, one on each side of the bottom of the beam.

To a large extent the depth of the beam can be varied to suit special conditions or modified for use as wall beams, the only alteration being that the sides and ends of the beams are made parallel.

The following advantages are claimed for this type of flooring: (1) Low initial cost; (2) soundproofness (3) fire-resisting; (4) the floors, being previously matured, can be used immediately they are placed in position; (5) no supports are required during erection; (6) floors can be constructed to take any load over any span; (7) the floor units can be combined with any class of structural frame work; (8) the units can be made with a smooth soffit, needing only a coat of whitewash to form a presentable ceiling, or roughened for a plaster finish; (9) the units are capable of forming a floor without any surfacing material, or of taking any composition or other wearing surface; (10) the units can, if desired, be constructed on the site, thus avoiding risks, cost and delay of transport.

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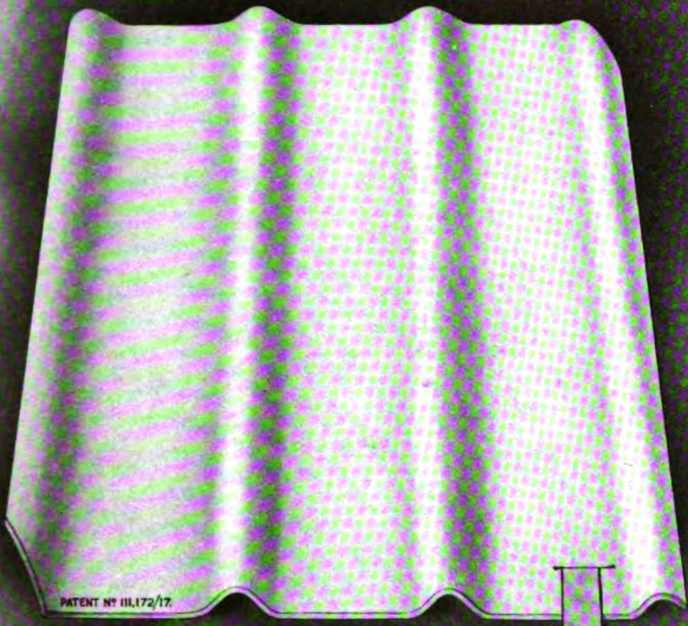

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Clean Shingle, ¾ in. mesh	,,	14	0
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Boarding for Shuttering—		Sawn.		Wrot.	
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Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £24 per standard
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Mild Steel Rods for Reinforcement—		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
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Do. do. in beams	,, ,,	50	6
Do. do. in floor slabs 4 in. thick	per yard super	5	4
Do. do. in floor slabs 6 in. thick	,, ,,	7	11
Do. do. in floor slabs 9 in. thick	,, ,,	11	6
Do. do. in walls 6 in. thick	,, ,,	8	2

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Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last, in narrow widths	,, ,,	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	,, ,,	1	1
Do. do. as last, in narrow widths	,, ,,	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are those current in the London area, namely:—Carpenters and joiners, 1/8 per hour; Labourers on building works, 1/3; Operators on concrete mixers and hoists, 1/4.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

MEMORANDA.

PROSPECTIVE NEW CONCRETE WORK.

Airdrie.—*Culverting.*—The T.C. has decided to proceed with the culverting of the South Burn, at an estimated cost of £433.

Annitsford.—*Houses.*—The Weetslade U.D.C. proposes to apply to the M.H. for sanction to erect 300 houses.

Bagshot.—*Sewage Works.*—The Windlesham U.D.C. has received sanction from the M.H. to borrow £11,120 in connection with the sewage disposal works.

Barnstaple.—*Houses.*—The T.C. has applied for sanction for a loan in connection with building 100 houses.

Bideford.—*Road.*—The T.C. has a scheme on hand for the construction of a new road from Northam to Bideford, estimated to cost £12,000.

Bishop Auckland. — *Road.* — Plans have been prepared for the construction of a new road, estimated to cost between £30,000 and £35,000.

Blackburn.—*Road.*—The Corporation proposes to apply for sanction to borrow £106,000 for the completion of the arterial road.

Bredbury.—*Road.*—The Lancashire and Cheshire County Councils are discussing with the Bredbury and Denton Urban District Councils a scheme for the construction of a main road between Bredbury and Denton.

Bridlington.—*Sea-wall.*—The M.H. has notified the T.C. of its approval of the scheme for the construction of a concrete sea-wall on the south side of the town, estimated to cost £107,000.

Burnley.—*Road.*—The Burnley Improvements Committee is considering a scheme for the construction of a new road, estimated to cost £103,000.

Church Stretton. — *Bridge.* — The R.D.C. proposes to construct a bridge over Longnor Brook, at an estimated cost of £700.

Clitheroe. — *Retaining Walls and Bridge.*—The Highways Committee proposes to build retaining walls, and to construct a ferro-concrete bridge over the brook.

Clowne.—*Houses.*—The M.H. is considering a scheme by the R.D.C. for the erection of 30 houses.

Colchester.—*Houses.*—The T.C. has applied to the M.H. for sanction to borrow £12,700 for the construction of 32 houses.

Derbyshire.—*Bridge.*—The C.C. proposes to construct a new bridge at Baslow.

Dewsbury.—*Sewage Works.*—The T.C. has applied to the M.H. for sanction to borrow £100,000 for the completion of the Mitchell Laithes sewage scheme.

Dublin.—*Road.*—A new trunk road is to be made from Dublin to Cork, estimated to cost about £1,500,000.

Dundee.—*Bridge.*—The T.C. has decided to construct a bridge over the L.M. & S. Railway at Fairmuir.

Epsom.—*Houses.*—The R.D.C. has applied to the M.H. for sanction to erect 300 houses.

Frinton-on-Sea.—*Defence Works.*—The U.D.C. has applied to the M.H. for sanction to borrow £10,000 for cliff-protection and sea-defence works.

Gainsborough.—*Road.*—The U.D.C. proposes to construct a street through the Bellwood's Lane district, at an estimated cost of £4,860.

Gillingham.—*Bridge.*—The T.C. has approached the Southern Railway Co. with a view to the construction of a ferro-concrete bridge across the railway, at an estimated cost of £9,000 to £10,000.

Girvan.—*Roads.*—The T.C. has applied to the M.T. for a grant towards the cost of constructing new roads in the town.

Glasgow.—*Docks.*—The Clyde Trustees have obtained Government assistance for the provision of a new dock, estimated to cost £2,000,000.

Hale.—*Sewage Works.*—The R.D.C. proposes to improve the sewage works at an estimated cost of £21,000.

Halesowen. — *Paving.* — The R.D.C. will apply to the Unemployment Grants Committee for assistance towards the cost of paving footpaths in the district, estimated to cost £18,000.

Hertfordshire. — *Roads.* — The C.C. has approved of a scheme for the construction of the portions in Hertfordshire of two new arterial roads, the total length of which will be 14½ miles, and is estimated to cost £623,500.

Honiton.—*Sewage Works.*—The M.H. is to hold an inquiry into the application of the T.C. for sanction to borrow £7,120 for sewage and sewerage works.

Huddersfield.—*Sewage Works.*—The M.H. has sanctioned the borrowing of

£4,944 by the Corporation in connection with the sewage works at Outlane.

Hunstanton.—*Defence Works.*—The U.D.C. proposes to erect a new sea wall, to be protected by three concrete groynes, estimated to cost £4,500.

Kirkcudbright.—*Bridge.*—Plans for a new ferro-concrete bridge, estimated to cost £20,000, have been adopted by the Stewartry of Kirkcudbright.

Lancaster. — *Road.* — The T.C. has received sanction to expend £50,000 on a new road from Owen Road to Scale Heath.

Leicester.—*Reservoir.* — The Corportion proposes to construct a new service reservoir near Saffron Lane, at an estimated cost of £8,400.

Limerick. — *Concrete Road.* — A reinforced concrete road is to be constructed at Limerick.

Little Lever.—*Sewage Works.*—The R.D.C. has applied to the M.H. for sanction to borrow £4,750 for improvements at the sewage disposal works.

Liverpool. —*Houses.* — The Corporation Housing Committee proposes to spend £60,000 on the improvement of unhealthy areas in Prince Edwin, Saltney and Blenheim Streets.

Liversidge. — *Sewage Works.* — The M.H. has sanctioned the borrowing of £12,000 by the Spenborough U.D.C. for the completion of the sewage works at Liversidge.

Llandovery. — *Houses.* — The T.C. has applied to the M.H. for sanction to erect 50 houses.

London (St. Pancras).—*Houses.*—The B.C. has applied to the L.C.C. for sanction to borrow £23,000 for the erection of houses.

Lowestoft.—*Road.*—The Corporation has agreed to a scheme for the construction of a by-pass road, at an estimated cost of £50,000.

Menai Straits. — *Bridge.* — A new ferro-concrete bridge is to be erected over the Menai Straits in place of the present suspension bridge.

Merthyr.—*Houses.*—The Corporation Housing Committee has approved a scheme for the construction of 150 concrete houses by unskilled labour.

Mexborough. — *Bridge.* — The West Riding C.C. is recommended to construct a new bridge over the canal near Mexborough, estimated to cost £5,000.

Nairn. — *Harbour Works.* — The Harbour Committee and the T.C. is considering the question of applying for a Provisional Order for the construction of a new harbour.

Newport, I.O.W.—*Quay Wall.*—The T.C. proposes to construct a quay wall at Blackhouse Lane.

Norwich. — *Tank.* — The Corporation has decided to construct a reinforced concrete compensating tank at the Heigham Works.

Redcar.—*Promenade.*—The T.C. has approved the scheme for the extension of the promenade, estimated to cost £5,000.

Resolven. — *Bridge.* — The Neath R.D.C. has given instructions for the preparation of plans and estimates for a new bridge over the G.W.R. connecting Rugby Road and Williams' Avenue, Resolven.

Saltcoats. — *Breakwater.* — The T.C. is considering the construction of a breakwater.

Southsea. — *Promenade.* — The scheme for the construction of a promenade from the Clarence Pier to the Grand Parade at Old Portsmouth has been approved for a grant.

Stirlingshire.—*Bridge.*—The Stirling T.C. is considering the construction of a new bridge in place of the present Drip Bridge.

Stockport. — *Houses.* — The Corporation has approved of the construction of 300 houses.

Stranraer. — *Sea Wall.* — The T.C. has agreed to construct a concrete sea wall at Port Rodie.

Swanage. — *Sea Wall.* — The U.D.C. has received sanction to borrow £3,400 for the repair of a sea wall.

Tividale. — *Sewage Works.* —The Upper Stour Valley Main Sewerage Board will apply to the M.H. for sanction to borrow £5,000 in connection with the improvements at the sewage works.

Torquay. — *Houses.* — The M.H. has sanctioned the construction of 300 houses.

Wellingborough. — *Houses.* — The U.D.C. has decided to construct 40 houses.

Wimbledon. — *Sewage Works.* — The M.H. has sanctioned the application of the T.C. to borrow £24,000 in connection with improvements at the sewage disposal works.

Woodford. — *Sewage Works.* — The U.D.C. has applied to the M.H. for sanction to borrow £14,080 for the construction of four new percolating filters at the eastern sewage works.

TENDERS ACCEPTED.

BAMPTON, DEVON.—*Reservoirs, etc.*—The U.D.C. has accepted the tender of Messrs. J. W. Scott & Sons, Bampton, at £2,843 5*s*. 6*d*., for the construction of two covered concrete reservoirs, engine house, etc.

BEDWORTH. — *Sewage Works.* — The Parochial Committee has accepted the tender of Messrs. C. P. Trentham, Ltd., at £9,182, for the construction of Bedworth sewage disposal works.

BIRMINGHAM.—*Houses.*—The Birmingham Public Works Committee has accepted two tenders for the erection of 1,500 concrete houses.

BIRMINGHAM.—*Tank.*—The Corporation has accepted the tender of Messrs. Grays Ferro-Concrete Co., Glasgow, at £23,249, for the construction of a reinforced concrete filtration and sedimentation tank.

GLASGOW.—*Sub-Station.*—The T.C. has accepted the tender of Messrs. Brown, Fraser & Co., at £1,202, for reinforced concrete work in connection with the erection of a sub-station at Baillieston.

HALESWORTH.—*Concrete Wall, etc.*—The Highways and Sanitary Committee has provisionally accepted the estimate of Messrs. Howard Bros., at £235 12*s*., for the construction of a concrete wall, fence, etc.

LONDON (HACKNEY).—*Foundations.*—The L.C.C. has accepted the tender of Messrs. Rowley Bros., at £1,747, for works in connection with the foundations, etc., of a new school on the Holcroft Road site.

OVERSTRAND, NORFOLK. — *Groyne.* — The Erpingham R.D.C. has accepted the tender of Mr. R. J. May, Trowse, Norwich, at £833 16*s*. 6*d*., for the erection of a new groyne at Overstrand.

POOLE.—*Reservoir.*—The Corporation has accepted the tender of Messrs. G. Pollard & Co., Ltd., Taunton, at £31,079 6*s*. 4*d*., for the construction of a new concrete covered reservoir of 5,000,000 gallons capacity, together with the laying and jointing of about 3,700 lineal yds. of 18-in. and 16-in. cast-iron rising and leading mains.

ROMFORD.—*Water Works.*—The R.D.C. has accepted the tender of Mr. R. Stroud, Ilford, for the construction of a concrete tank and other works.

ST. PETER PORT, GUERNSEY.—*Deck.*—The Board of Administration has accepted the tender of Mr. N. Buckley, Dorchester, for the removal of a timber deck and the construction of a new deck in reinforced concrete.

SCARBOROUGH.—*Café.*—The T.C. has accepted the tender of Messrs. C. H. Sugden & Co., at £1,830 10*s*., for the reinforced concrete work in connection with the erection of a new café at Peasholm Gap.

SINGAPORE.—*Post Office.*—Messrs. Perry & Co. (Bow), Ltd., have secured the contract for the construction in reinforced concrete of the new General Post Office. The cost of the building will be about £1,000,000.

SOUTHEND-ON-SEA. — *Houses.* — The T.C. has accepted a tender, at £26,208, for the erection of 66 concrete houses on the Sutton Road site.

STAFFORD.—*Floor.*—The T.C. has accepted the tender of Messrs. F. Espley & Son, at £434, for laying a concrete floor in the Fish Market.

TILBURY.—*Road Improvements.*—The U.D.C. has accepted the tender of Messrs. F. Mitchell & Son, Manchester, at £5,610, for reconstructing in reinforced concrete 11,200 sq. yds. of Dock Road.

[⁂ Other tenders accepted are given on p. 123.]

RECENT PATENT APPLICATIONS.

192,035.—Scott & Son Proprietary, Ltd.: Centrifugal apparatus for manufacturing concrete pipes.

199,350.—J. E. Lauhoffer and O. E. Lauhoffer: Process for the manufacture of asbestos-cement compositions.

207,084.—W. F. Owsley: Apparatus for levelling and surfacing concrete paving.

207,111.—E. Beckett: Concrete slab walls.

207,372.—J. P. Sainrapt and Soc. Des Lingaux et Agglomeres: Centrifuges, Joints for ferro-concrete pipes.

207,452.—Internationale Siegwartbalken-Ges: Method of producing upwardly-tapering concrete poles.

207,714.—F. A. Macdonald: Concrete and reinforced concrete hollow pre-cast tubes.

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CONCRETE AND CONSTRUCTIONAL ENGINEERING

MARCH 1924 VOL. XIX. No. 3

A MONTHLY JOURNAL for Engineers, Architects, Surveyors and Contractors and all interested in Cement, Concrete, Reinforced Concrete, Fire-Resisting Construction and Structural Steel.

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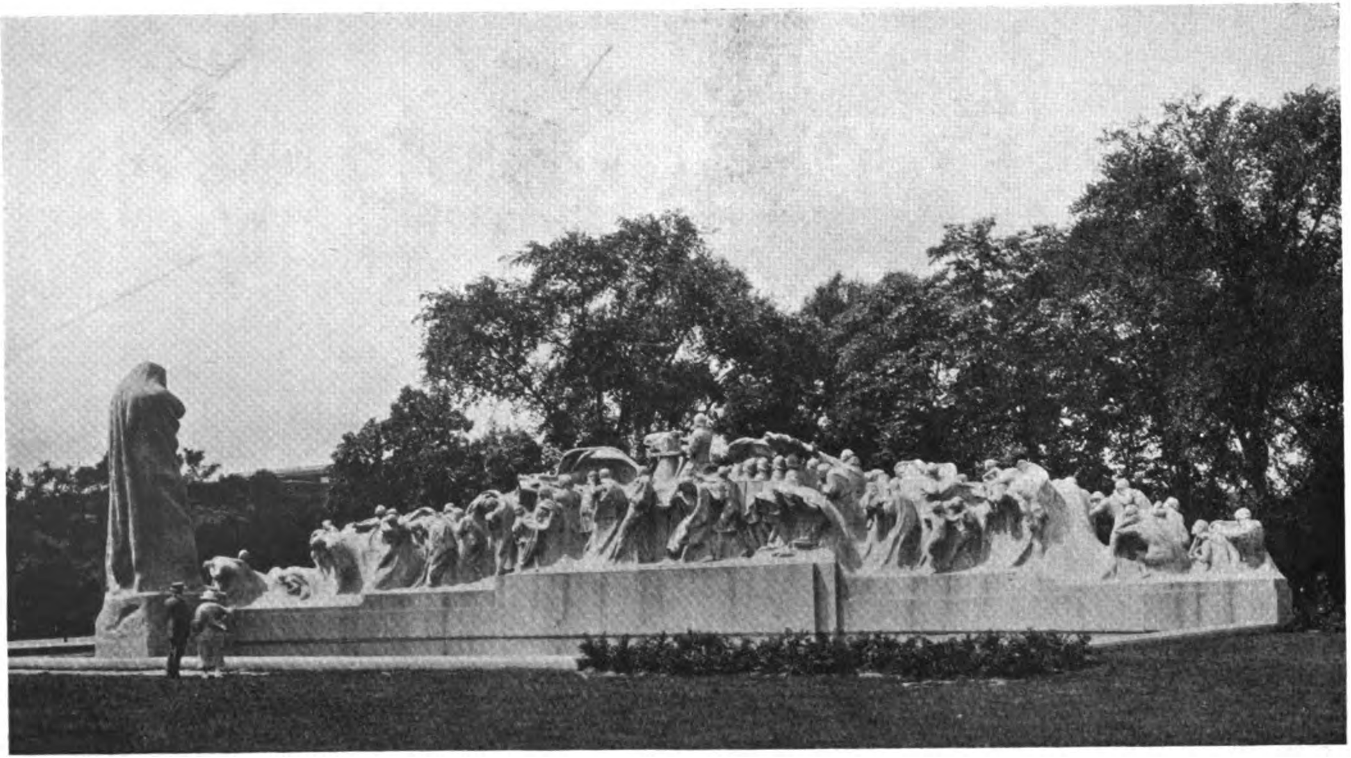


[Mr. Lorado Taft, Sculptor.

"THE FOUNTAIN OF TIME": STATUARY GROUP IN CONCRETE.

(*See p.* 139.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIX. No. 3. LONDON, MARCH, 1924.

EDITORIAL NOTES.

CONCRETE AND HOUSING.

BEFORE the effort to make up the deficiency in housing was undertaken some five years ago concrete houses were practically unknown in this country, and to most people they were an experiment entered upon as a supplement to the traditional brick. At that time even timber construction was advocated, and although wooden houses were not built in any considerable numbers a large number of Army huts were converted into dwellings. However, in spite of the misgivings of those who had no practical experience with the material, many thousands of concrete cottages were built up and down the country, and in spite of the prophecies—perhaps prejudiced—to the effect that they would fall down, or, alternatively, that they would " leak like sieves," they are still in existence and making homes as weatherproof and as comfortable as those built of any other material. In addition to giving accommodation to thousands of people who would otherwise still have been homeless, these cottages have provided an object lesson to all concerned with the provision of houses, in showing that the dwelling accommodation of the nation, on which social reformers tell us depend the well-being and contentment of the people, is not necessarily to be limited according to the dictates of a small section represented by the bricklayers.

Conditions to-day are precisely the same as they were five years ago so far as the demand for houses and the capacity of the industry to build them is concerned; the shortage of accommodation is no less, and the supply of skilled labour has not increased. On the other hand, materials are available in greater quantities at reduced prices and wages are considerably lower. The result of these lower costs is that the small brick house which five years ago cost upwards of £1,000 could now be built for about £500 if, and this is the all-important point, there were sufficient skilled labour to make up the deficiency at the rate of 200,000 per annum, which, according to statements of the Minister of Health, is the object of the Government. The fact is, however, and it is admitted by the Government and both employers and operatives in the building industry, that there are not enough skilled men to build anything like the number of houses required; it was stated the other day by the Minister of Health that there were now approximately half the number of bricklayers there were in 1913.

We are thus faced with the position that the cost of houses has fallen to a figure low enough to induce the Government to launch a new housing programme, and for many people requiring a house to invest in building, but the demand cannot be met because there are not enough skilled men available to build them in brick. Under these circumstances it is not surprising that the thoughts of the Government and others interested in the provision of houses have turned to concrete, not in the nature of an experiment or a temporary expedient, but as a material which has already been used in this country for thousands of cottages with satisfactory results. At the present time large concrete housing schemes, comprising many thousands of cottages, are being carried out, under the 1923 Housing Act, at Edinburgh, Belfast, Swansea, Merthyr, Southend-on-Sea, and elsewhere, and in each case concrete was selected in preference to brick on account of cost and speed of erection. It has been abundantly proved on schemes where the same designs have been carried out in concrete and brick that the former is considerably cheaper, but the crux of the matter, and at the present time perhaps the most important point, is that an unlimited number of houses can be built in concrete while the number of brick houses which can be provided is strictly limited by the number of bricklayers available. Several systems of concrete cottage construction, such as the various methods of forming *in situ* walls and the pier and slab systems, do not require the services of the bricklayer at all ; it is not even necessary to use a trowel, and local unemployed labour can be quickly trained to carry out the work. With concrete block construction in many districts the bricklayers claim that no one but a member of their union shall lay concrete blocks, but the fact that one concrete block is usually equivalent to eight bricks considerably reduces the number of bricklayers required on this type of construction as compared with brickwork. Bearing on this question we may quote a recent letter in *The Times* by Mr. Curtis Green, A.R.A., the well-known architect, who said : " I have had some experience of building houses with concrete blocks, and good houses can be economically built of this material provided that the aggregate can be obtained locally." After giving an instance where the compulsory use of bricklayers for laying concrete blocks had unnecessarily driven up the cost, he said : " Houses can be built of concrete blocks without drawing on the limited number of available bricklayers, provided the unions agree to the employment of semi-skilled labour." We suggest that one of the first acts of the Government in its endeavours to get houses built should be to get the trade unions to remove this restriction, and allow builders to train labourers to lay concrete blocks.

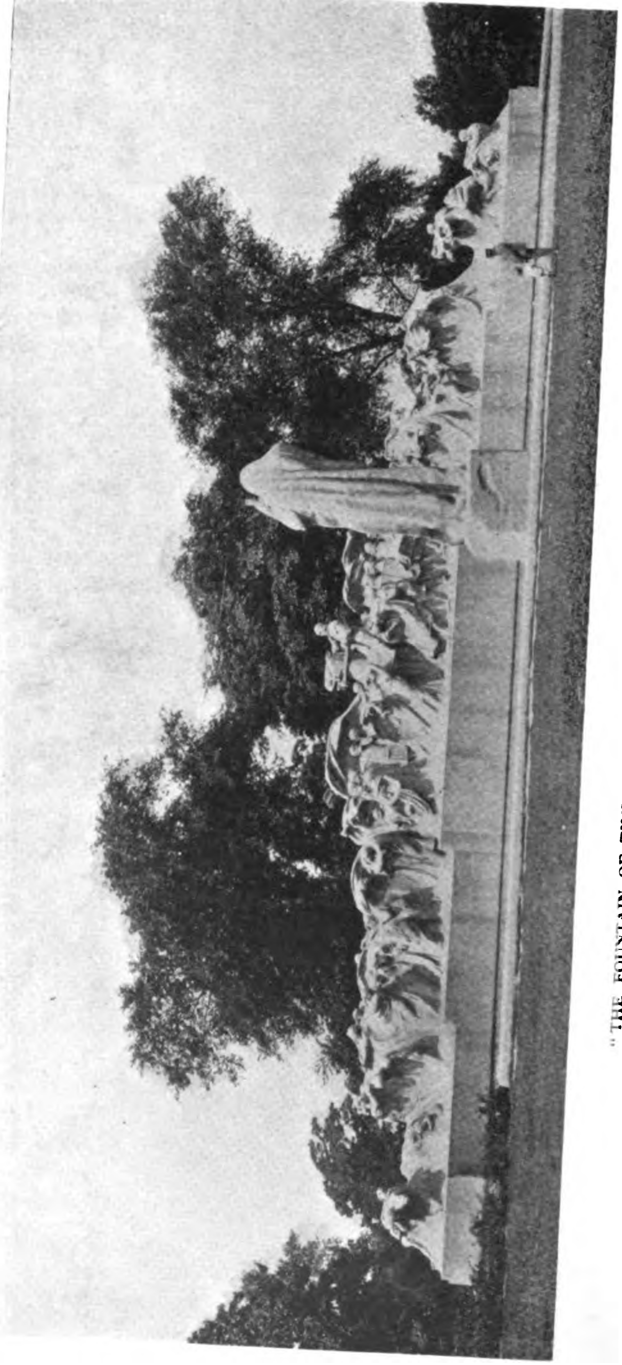
In view of the public interest in concrete cottages we are printing a large new edition of Mr. Lakeman's book on " Concrete Cottages, Bungalows and Garages," further particulars of which will be found on p. 142.

ARCHITECTURAL USES OF CONCRETE.

To those who are unacquainted with what is being done abroad it will probably come as a surprise to know that such a monumental piece of sculpture as " The Fountain of Time," illustrated in this issue, has been executed. The conception of one who is in the front rank of American sculptors—Mr. Lorado Taft—this work has been very favourably received by the public and by the art critics whose writings we have seen. Nowhere have we seen any suggestions that the group would have been better carried out in stone or marble. According to those qualified to give an opinion and who have seen it, the texture of the concrete is all that can be desired; so we have a monumental group of statuary in Chicago which is satisfactory from the points of view of stability, permanence and appearance, while at the same time showing a very large saving compared with what the work would have cost in natural stone; in fact, we are informed that the cost of carving this conception in stone would have been so great as to be prohibitive, and that if the lower cost of concrete had not been taken advantage of the work could never have been executed. As will be seen the group represents over one hundred figures passing a representation of Time, the motto being "Time goes, you say? Ah! no. Alas! Time stays; we go."

Some exceedingly interesting experiments in surface treatment have been put into practice in this group. Mr. John J. Earley, who was responsible for the construction of the work, has made some exhaustive experiments in the harmonious blending of aggregates, and has evolved a number of formulæ for the production of concretes whose surfaces blend to a uniform colour at certain distances. As stated in Mr. Earley's interesting account of the work on p. 139, the concrete for the group was composed of river gravel selected to contain particles varying in colour from white to yellow to brown, which after being crushed and mixed with cement, presented a surface uniform in colour at a distance of 100 ft., the film of cement, of course, being scrubbed from the surface before the final set of the concrete had taken place. By the careful selection of aggregates, states Mr. Earley, concretes may be designed to resolve into one hue at any distance from 25 ft. for interiors to 1,000 ft. for bridges or other structures to be seen from great distances.

With the exception of some figures by Mrs. Phœbe Stabler, illustrated in our issue for October, 1922, and one or two other examples, concrete as a medium for statuary is hardly known in this country, but this remarkable American group shows that its possibilities in this direction are practically unlimited, only awaiting someone to take advantage of them. The cheapening of the execution of the sculptor's art which is presented by concrete should permit of our public places being adorned with a greater profusion of statuary, which is at present often ruled out on account of cost.



"THE FOUNTAIN OF TIME": STATUARY GROUP IN CONCRETE. (*See p.* 139.)

[*Mr. Lorado Taft, Sculptor.*

"THE FOUNTAIN OF TIME."

In our Frontispiece and on p. 138 we illustrate the largest piece of sculpture so far carried out in concrete. This is "The Fountain of Time," unveiled last year at Chicago. The sculptor is Mr. Lorado Taft, and the work was carried out by Mr. John J. Earley, whose exposed-aggregate work at the Church of the Sacred Heart, Washington, was illustrated and described in our issue for January last.

In some notes on this monumental piece of concrete work, Mr. Earley says:—

Mr. Taft was beset by the same trouble which has harassed sculptors for many years; namely, the cost of preserving his work in a permanent material, a difficulty which has always exercised a restraint on the practice of the art and at certain times has almost completely discouraged it. Mr. Taft's problem was particularly difficult because "The Fountain of Time," which is probably the largest group of sculpture on a single base in the world and on which he had spent seven years of labour and $50,000, would necessarily be lost unless an additional $250,000 would be found available to pay the cost of translating his work into stone or metal or unless another material could be found which would be both economical and artistic. Mr. Taft's previous experience prompted him to believe that his "Fountain of Time" might be preserved in concrete if one could be found who understood the medium and who appreciated the artistic requirements of the subject.

The economy and adaptability of concrete rests upon its plastic nature. It is well known that less force is required to work and to form a plastic than a solid mass and, whether that force be considered as fuel or as labour, less force certainly means less cost. Likewise when more perfect knowledge has permitted the development of a more perfect technique plastic masses will be more adaptable than solids, they will be under more perfect control, and with better control will come better products and greater economy.

Only when we are able to do all the work that must be done to concrete while it is in a plastic state will we be able to appreciate the possibilities of this wonderful material. Concrete as an artistic medium becomes doubly interesting when we realise that in addition to its economy it possesses those properties which are the most desirable of both metal and stone. Metal is cast, it is an exact mechanical reproduction of the artist's work, as is concrete; but metal, because of its colour and the peculiar quality of its surface, is hard to use, that is, it is hard, particularly hard in large subjects, to fit into ordinary surroundings. On the other hand stone has a colour and texture which is easier to adjust to general use and environment. Concrete is largely stone and partakes of the properties of stone, and when surface-treated as was the "Fountain of Time" has a surface almost entirely of stone. "The Fountain of Time" presented the most difficult problem of its kind that has ever been brought to my studio. Unlike other sculptural groups, which are usually composed of separate figures on a common base touching each other only at certain points, this great group presented a wave-like mass from which projected and into which receded nearly one hundred colossal figures.

CONSTRUCTION.

The features of the work which introduced unusual requirements were: first, the shape of the group, which was a continuous structure and not a series of assembled units; second, a complex fold which instead of being a receptacle into which the concrete could be poured was a dome under which it must be placed and with which it must be maintained in contact while hardening; third, a core which would generally follow the configuration of the mould at a certain distance from it to regulate the thickness of the concrete and to support it in place, in contact with the mould while setting; and, fourth, a concrete which would fill perfectly all the re-entrant angles of a complicated mould, would not change volume and shrink away from the mould while setting, would attain an early strength to permit the removal of the mould and the exposure of the aggregate before final set, and which would when cleaned present a surface of predetermined colour and texture.

We were considerably concerned about what to do with water which might collect in hollows among the figures. If we altered the shape of the mass sufficiently to eliminate the hollows we would naturally change the design of the group. But the problem was solved by resolving the entire structure into the elements of a house; a foundation, a first story, a second story, and a roof. The roof was built as high as possible but yet below a level at which the figures met in a continuous mass. It was pitched towards the centre and drained by down-spouts. The figures which formed the second story extended above the roof as an irregular parapet. They were arbitrarily divided into twenty-six sections of such size as estimated to contain the amount of concrete which could be placed in a normal day's work by the most efficient number of men. The joinings between sections were always vertical and located in recesses. The first story and the foundations presented no unusual features.

"The Fountain of Time," with nearly 100 figures in a continuous form 120 ft. long, 18 ft. high and 14 ft. wide, required a mould too large and too complicated to be filled by usual methods and formed a cast too large to be made solid. The mould, which was made of plaster of paris heavily reinforced with jute fibre and 2-in. iron pipe, was divided horizontally into 30-in. courses. It was built from bottom to top and from station to station. The bottom course rested upon timber which was fastened to the base below the feet of the figures in the same position relative to the figures that the top edge of the concrete base would occupy. The timber so formed the first course of the mould that it fitted on to the top edge of the concrete base, and was kept in alignment and supplied by it. At each station there was a zone the height of the model and 1 in. wide where the moulds lapped. This was done in order that after the first section had been poured each concrete cast would act as a guide for the assembly of the next section of mould and as a bulkhead for one end while a temporary bulkhead closed the other. Because the group is 255 ft. in girth it was thought wise not to depend altogether for alignment on the top edge of the base and the vertical jigs but to leave three or four narrow sections for closures in which any slight misalignment could be adjusted. It was found that the mould for the last pouring lined up with the first casting, without need of adjustment.

Two particularly interesting features of the mould were the sections across the top extending from side to side in the form of bridges, which were self-sustaining and which supported the surrounding pieces of mould in a construction similar to the masonry vaults of certain Gothic churches. The other feature was the arrangement of the mould under the figures which projected almost horizontally from the general mass. Before final set had occurred it was necessary to remove these pieces of the mould and to surface the concrete, but it was also necessary to remove the supports from the projecting figures before the concrete had developed considerable strength, and if this were done it would certainly fail. To overcome this difficulty the pieces of the mould were made with the shape of the joints reversed. Ordinarily the joints are made to resist pressure from within; they are interlocking and can only be broken by removing the pieces of the mould in the reverse order to that in which they are made. But these pieces were made so that they could be removed separately, replaced and propped after the concrete had been surface treated. The mould for "The Fountain of Time" was probably the largest plaster piece mould ever made. It consisted of about 4,500 pieces of various sizes; the smallest were about 12 in. across and weighed 25 lbs., the largest were about 30 in. by 4 ft. and weighed over 1,000 lbs.

In preparation for the core which was to establish the thickness of the concrete and keep it in contact with the mould a survey of the model was made and contours were drawn at every foot of elevation. Outside of the model wires were stretched parallel to the centre line; from these measurements were taken which were translated into their co-ordinates in order that the work might be laid out from a centre line. The contours were sawn from wood and assembled in their proper places. They were covered with metal lath and coat of cement mortar composed of one part Portland cement and three parts sand. The mortar was applied with a pointing trowel and without an attempt to compact it; it was a lean mix and hard to apply, but it hardened and formed a very porous base well suited to the work it was intended to do.

When the core was completed timbers were attached vertically to the base by bolts screwed into sockets provided for that purpose. The timbers were connected to each other at the top by joists, and formed supports against which the mould was braced; being attached to the concrete base they were by far superior to supports set in the soft soil which surrounded the fountain. They also served as pole derricks to which was attached rigging and by which was hoisted all the moulds and materials.

The concrete was made of river gravel selected to contain particles varying in colour from white to yellow to brown and crushed and arranged in size so that at the distance of 100 ft. the surface of the concrete would appear uniform in colour and texture. The general hue of the concrete is yellow red of bright value and weak chroma. This is called a "100 ft. concrete" because the particles on the surface blend to a uniform colour and texture at that distance. Concretes may be designed to resolve to hue at any distance at 25 ft. for interiors, at 50 ft. or at 1,000 ft. for bridges.

In order that the concrete might completely fill so complicated a mould it was necessary to mix it very soft, and in order that it might not shrink away from the dome-like surface of the mould it was necessary to mix it very stiff. This difficulty was overcome by bringing about a change in consistency while the concrete was in the mould. The core was so constructed that it would extract the excess water but at the same time leave sufficient for the hydration of the cement. Although the most important parts of the work, such as heads and arms, were at the top of the moulds, the most difficult position to fill, the concrete showed no tendency to shrink away from the mould owing to the extreme density developed when the excess water was extracted.

SLAG FROTH AS AN AGGREGATE.

For insulating purposes or where an exceptionally light aggregate is required, a material made by blowing air and steam into molten slag appears to offer considerable promise. The frothing of the molten slag may be effected in various ways, but in each it is essential to keep the slag well stirred during the formation of the froth and to introduce water in the process. Dry air or superheated steam will not produce a good froth, but this is readily formed if a little water is present. The froth is conveniently passed between water-cooled rolls which chill it and prevent the air-bubbles from coalescing and also give it a convenient shape.

Most blast-furnace slags can be used for the purpose, provided they do not contain more than 3 per cent. of iron oxide in a form in which it can easily be oxidised. The best results are obtained when there is less than 40 per cent. of alumina, 17–55 per cent. of lime and other bases and 30–60 per cent. of silica.

The porosity can be varied by varying the temperature and the rate at which the air or steam is blown into the molten slag, but a material weighing only 9-18 lbs. per cubic foot is comparatively easy to produce; under favourable conditions a slag froth with a porosity of 97 per cent. and weighing only 4½ lbs. per cub. ft. can be made.

Bricks or slabs made of such an aggregate and Portland cement have an unusually high heat-insulating power and allow less than one-fifth as much heat to pass through them as would ordinary concrete.—*Stahl und Eisen.*

CONCRETE COTTAGES.

THE provision of working-class houses is now receiving a great deal of attention, and there is much talk of concrete cottages. The reason is not far to seek. One of the most serious obstacles in the way of the erection of brick buildings in any large number is the shortage of bricklayers, and it is only natural that methods of construction which do not require the services of such a rarity as a bricklayer seeking work should receive the earnest consideration of all who are concerned with the urgency of the housing problem. Letters have appeared in the Press from some of the leading architects of the day advocating the use of concrete for small dwelling-houses, and in the light of the experience obtained as a result of the thousands of houses already built in concrete it is certain that this material will play a prominent part in the housing schemes of the near future.

At this opportune time we have in the Press a second edition of Mr. Albert Lakeman's book, "Concrete Cottages, Bungalows, and Garages." This is an entirely new work. It is an exhaustive treatise on the subject of concrete cottage construction. Mr. Albert Lakeman, M.S.A., M.I.Struct.E., Hons. Medallist (Construction), has had a very large experience in the design and erection of all classes of concrete buildings, and his own knowledge of the subject and the experience gained by others in the construction of small concrete buildings are embodied in this book in such a form that this type of building can be erected without further assistance. Seven designs for cottages, bungalows and garages, with different accommodation, have been specially designed by the author for construction in concrete, and with each design is given all the information necessary for its erection, perspective drawings showing the same designs with flat and pitched roofs, plans, sections, full working drawings, and detailed bill of quantities.

The completeness with which these designs have been worked out has not been done with any view to supplanting the architect, and all who wish to have a house built for them, or builders engaged to erect concrete houses, are strongly advised to consult an architect. But the book is also written for architects, and it is realised that with a comparatively new material such as concrete, in which a large number of architects have as yet had no experience as a medium for the construction of a complete building, it is necessary that there should be a book which will help the architect in the design of such buildings. To get the best results out of the material it is not sufficient simply to use concrete in place of bricks. Concrete has many characteristics of its own. Whether the method of construction be monolithic, piers and slabs, or concrete blocks, the system or the units employed are vastly different from the standard size brick, and call for corresponding differences in design; it is in order to point out what is possible in this direction that the designs for various types of cottages, bungalows, and garages have been elaborated, in the hope that the book will in some measure set a good standard of design for this type of building.

With a view to getting the advantages of small concrete dwellings known as widely as possible, this volume, which is copiously illustrated in the text and contains drawings by Mr. T. Raffles Davison, Hon. A.R.I.B.A., and coloured plates, we are printing in two editions, one strongly bound in cloth at 5*s*. net (by post 5*s*. 6*d*.), and one in paper covers at 3*s*. 6*d*. net (by post 4*s*.). The book will be ready in a few days, and copies may now be ordered.

THE DESIGN OF REINFORCED CONCRETE ARCH RIBS.

AN ACCURATE SHORT-CUT METHOD OF OBTAINING A PRELIMINARY DESIGN.

By A. P. MASON, B.Sc. (Lond.).

THE following method of fixing up the proportions of an arch rib is an original one developed by the writer, after a great deal of investigation into the subject. The usual procedure is one of trial and error. Reference is made to a number of existing arches working under similar conditions to the one contemplated, and from the data gathered certain sizes are assumed for the arch rib at crown, quarter-point, and springing. The assumed arch is then analysed by the elastic theory, which in its most simplified form is a laborious task, and the moments and thrusts produced by the given system of loading at the various sections deduced therefrom. From these figures the stresses in the concrete and steel are calculated. If these do not come within the desired limits fresh sizes must be assumed and the whole procedure repeated, since altering the arch also changes the magnitude of the moments and thrusts to be dealt with.

The object of the writer is to eliminate much of the labour usually required, but at the same time to arrive at results which can be relied upon to be very near the truth and certainly accurate enough upon which to base a preliminary design.

Briefly, the method is first to calculate the bending moments and thrusts which will have to be dealt with, and then to proportion the material accordingly, as contrasted with the usual method of first fixing on a certain arch and analysing it to see if it is suitable. The calculations become as definite as those for a simple beam.

If influence lines for bending moment and normal thrust be drawn for arches of various proportions and rise ratios, it will be found that they are all of similar shapes, and rise to their maximum values at about the same points. Typical influence lines are given in Diagrams 1 and 2, and the position at which maximum, minimum and zero values occur are indicated.

If, then, the maximum and minimum values of bending moment and normal thrust due to unit loads are known for any given arch these may be set up as ordinates in their appropriate positions along a base line, and the curves drawn in so as to match in shape the typical curves given.

In order to obtain a means of arriving at these extreme values the writer has investigated a number of arches of various rise ratios, of which the proportions are such that the stresses at crown, quarter-point, and springing are within desirable limits. The maximum and minimum values of bending moment and normal thrust have been plotted with respect to rise ratio, as shown in Diagrams 3 and 4.

TO DRAW THE INFLUENCE LINES FOR BENDING MOMENT.

As an example, take an arch of which the span is 120 ft. and the rise 30 ft.

The rise ratio is $\frac{30}{120} = 0{\cdot}25$.

Draw a horizontal base line to scale to represent the span of the arch in feet, measured centre to centre of the springings. Considering bending moments at the crown, set up an ordinate on the positive side of the base line at 0·5 span, that is, at 60 ft. from the left-hand end. Referring to the curve for maximum positive moment at the crown (Diagram 3) it is found that the value for a rise ratio of 0·25 is 0·0405 *WL*. The bending moment due to a unit load of one ton on a 120 ft. span is therefore $0{\cdot}0405 \times 1 \times 120 = 4{\cdot}86$ tons-ft. Set up this value to scale on the ordinate at 0·5 span. The influence line will cut through the base line at 0·365 *L* and 0·635 *L*, that is, at points distant 43·8 ft. and 76·2 ft. from the left-hand end, and for loads at either of these points the bending moment at the crown will be zero.

Next set down ordinates on the negative side of the base line at 0·24 *L* and 0·76 *L*, that is, at points distant 28·8 ft. and 91·2 ft. from the left-hand end. Referring to the curve for maximum negative moment at the crown (Diagram 3) it is found that the value for the given rise ratio is 0·009 *WL*, representing a bending moment of — 1·08 tons-ft. Mark off this value on both ordinates. It only remains to draw a fair curve through the points to match the typical curve given in Diagram 1 to complete the influence line.

To draw the influence line for thrust at the crown it is only necessary to set up an ordinate at midspan. The thrust due to a unit load in the given case is 1·01 tons. This is found from Diagram 4. Set up this value on the ordinate and draw in the influence line to match the typical curve in Diagram 2.

Influence lines may be drawn in this manner for the springing and quarter-point.

With regard to the influence line for normal thrust at the quarter-point, it should be noted that there is a sudden increase in thrust as the load, coming from the adjacent springing, passes over the section. In Diagram 4 there are two curves in connection with this, one giving the thrust due to a unit load just about to cross the section, and one for the thrust when it has just crossed. This sudden rise in the influence line is more marked in arches of large rise ratio.

ARRANGEMENT OF LOADING GIVING MAXIMUM STRESSES AT THE CROWN.

When heavy point loads, such as the Ministry of Transport Standard Loading, are crossing the bridge the heaviest wheel load should be placed at the crown, and so much of the span as is capable of producing positive moment at the crown should be loaded. The loaded length will be from 0·365 to 0·635 span, measuring from the left-hand end. This arrangement gives the maximum positive bending moment at the crown, and when this moment is combined with the corresponding normal thrust it produces the worst stresses. Where the loading is uniformly distributed, or if the rise ratio be small, a worse case may be produced when the whole span is loaded. This case gives the greatest normal thrust with a comparatively small bending moment.

ARRANGEMENT OF LOADING GIVING MAXIMUM STRESSES AT THE SPRINGING.

The arrangement of loading producing maximum positive bending moment generally gives the worst springing stresses, but if time permits it is advisable to test for the arrangement giving maximum negative moment. In the former case, considering the left-hand springing, the heaviest load should be placed at 0·635 span and the arch loaded from 0·395 span to the right-hand end. In the latter case the heaviest load should be at 0·175 span and the arch loaded from the left hand end to 0·395 span.

ARRANGEMENT OF LOADING GIVING MAXIMUM STRESSES AT THE QUARTER-POINT.

The arch should be loaded from the left-hand end up to 0·395 span, with the heaviest load at the quarter-point. This arrangement gives the maximum positive bending moment. If the rise ratio be small a worse case may be produced by loading the arch from 0·395 span to the right-hand end, with the heaviest point load at 0·56 span.

Having obtained the total bending moments and corresponding normal thrusts at the various sections, the sizes of the rib at these points may be obtained by using any method for dealing with combined bending and direct thrust. The writer found that the ratio of thickness of the arch rib at the springing to the thickness at the crown varied from 1·5 when the rise ratio was 0·1 to 2·0 when the rise ratio was 0·3, provided the breadth were kept constant. The reason for this is that in arches of small rise ratio the determining factor is direct thrust which increases only slightly towards the springing. In the case of arches of larger rise ratio the thrust is comparatively small, increasing towards the springing, but the bending moment is also much greater at that point; hence a deeper section is necessary. The curves reproduced in this article are all based on this assumption.

EFFECT OF TEMPERATURE VARIATION.

As a further refinement the effect of temperature rise and fall may be included, but to do this an approximate size must be assumed for the arch rib at the crown. Diagram 5 gives values for thrust which are co-efficients of $\frac{Tbt_c^3}{L^2}$ and values for bending moment which are co-efficients of $\frac{Tbt_c^3}{L}$, the notation being as given on the Diagram.

In order to make an allowance for the effect of arch shortening, the average stress throughout the arch due to dead and live loads and temperature variation must be computed. For example, when considering the crown section, the thrusts at the quarter-points and springings must also be found. Dividing these thrusts by the cross-sectional areas of the rib at the points to which the thrusts apply gives the average stresses at both springings and quarter-points and the crown. The mean of all these stresses is approximately the average stress throughout the arch. Hence, to find the effects of arch shortening multiply the thrusts and moments produced by a fall in temperature of 1° F. by the factor

Average stress due to live and dead loads and temp. variation. ÷ 1584.

It is not necessary to consider temperature variation and arch shortening when preparing a preliminary design provided the arch is built up from a number of narrow flexible ribs, but in the case of a continuous arch ring, that is, one the whole width of the bridge, these two factors often outweigh the dead and live load effects, and cannot therefore be neglected.

The foregoing applies to all arches with open spandrels in which the shape of the centre line is parabolic or nearly so. The only data required are the span and rise of the arch, the type of loading, and the range of temperature variation.

TYPICAL INFLUENCE LINES FOR BENDING MOMENT INDICATING POSITIONS AT WHICH EXTREME VALUES OCCUR

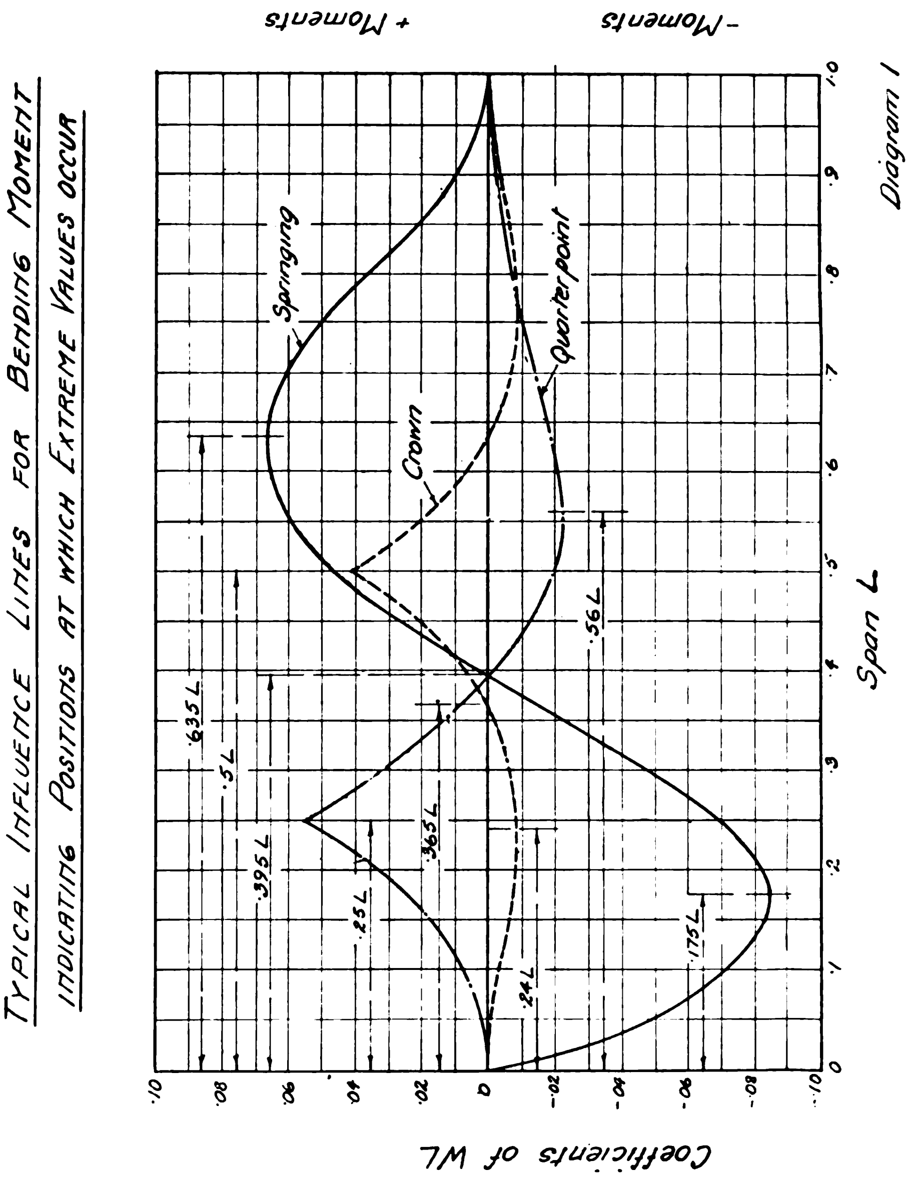
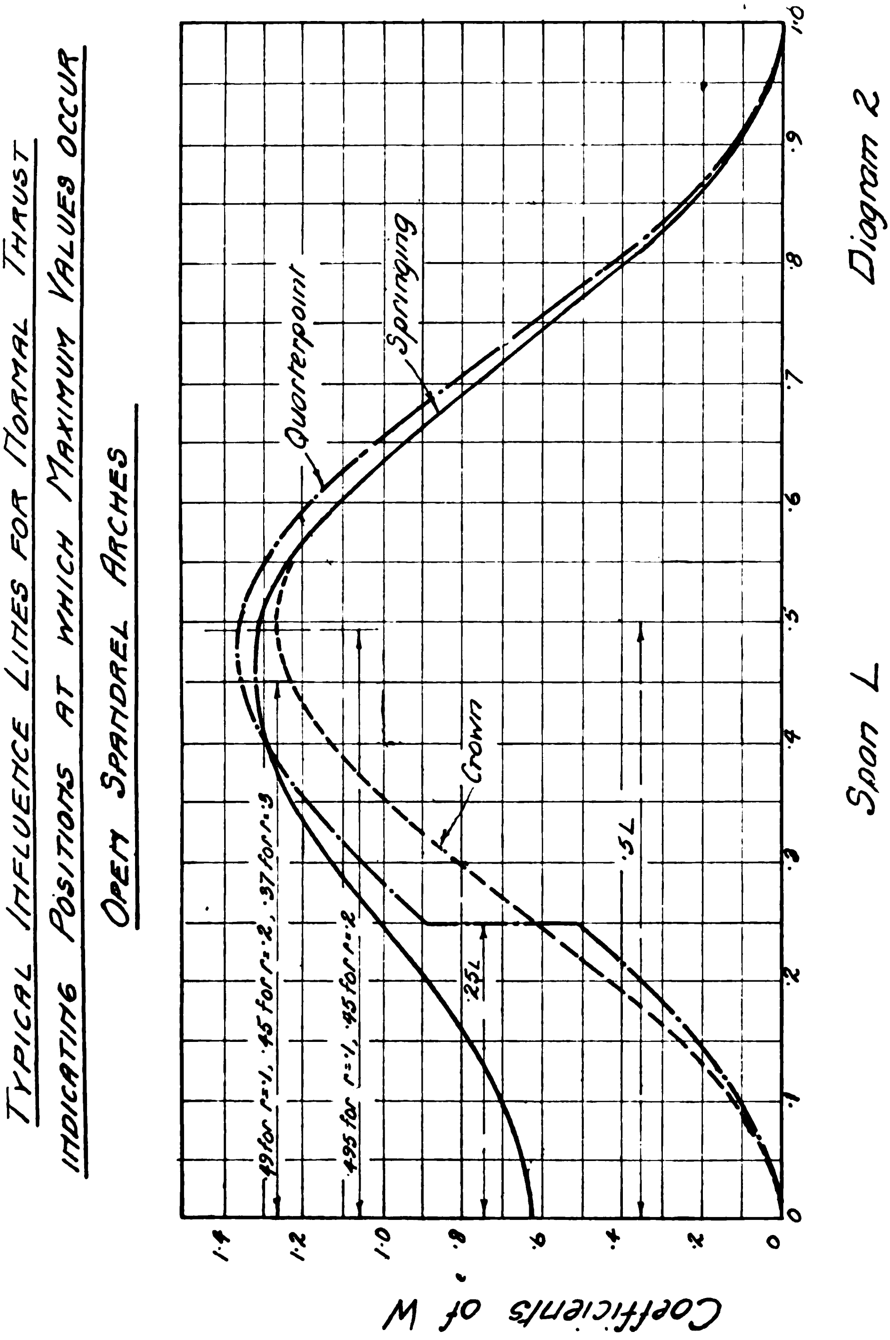


Diagram 1

THE DESIGN OF REINFORCED CONCRETE ARCH RIBS. (See p. 143.)



TYPICAL INFLUENCE LINES FOR NORMAL THRUST INDICATING POSITIONS AT WHICH MAXIMUM VALUES OCCUR

OPEN SPANDREL ARCHES

Diagram 2

THE DESIGN OF REINFORCED CONCRETE ARCH RIBS. (See p. 143.)

MAXIMUM VALUES OF BENDING MOMENT.

OPEN SPANDREL ARCHES.

To employ the values shewn in the curves for drawing influence lines for any arch, multiply by the span length, plot in the positions indicated by the typical influence lines, and draw in the curves to a similar shape.

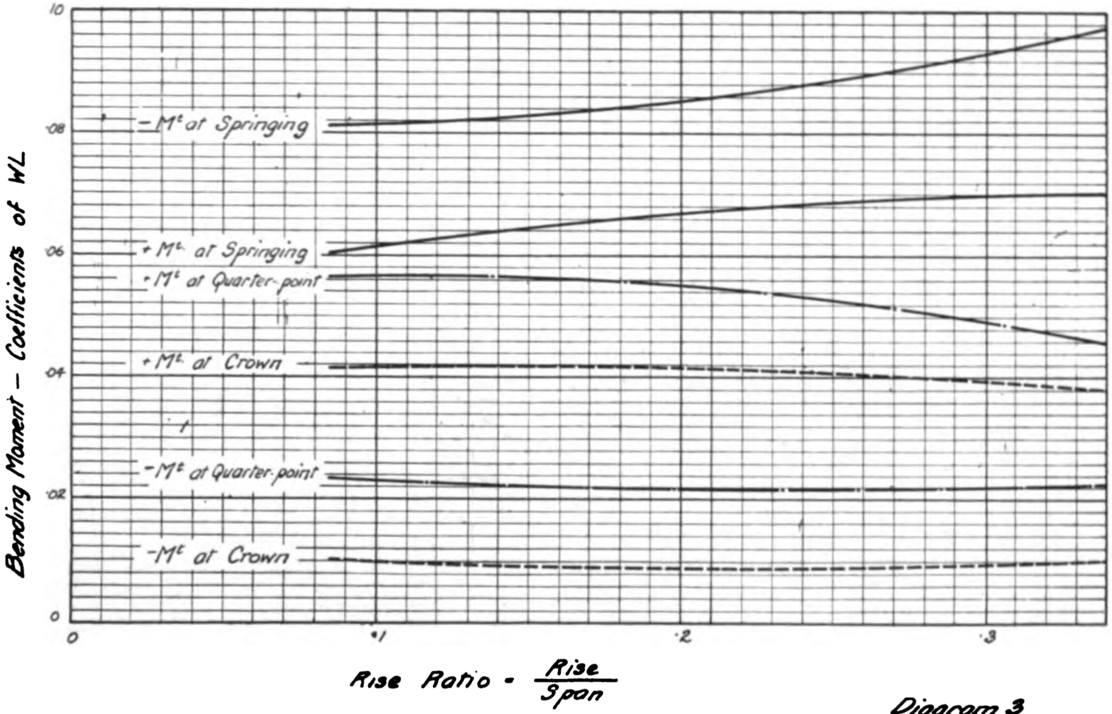
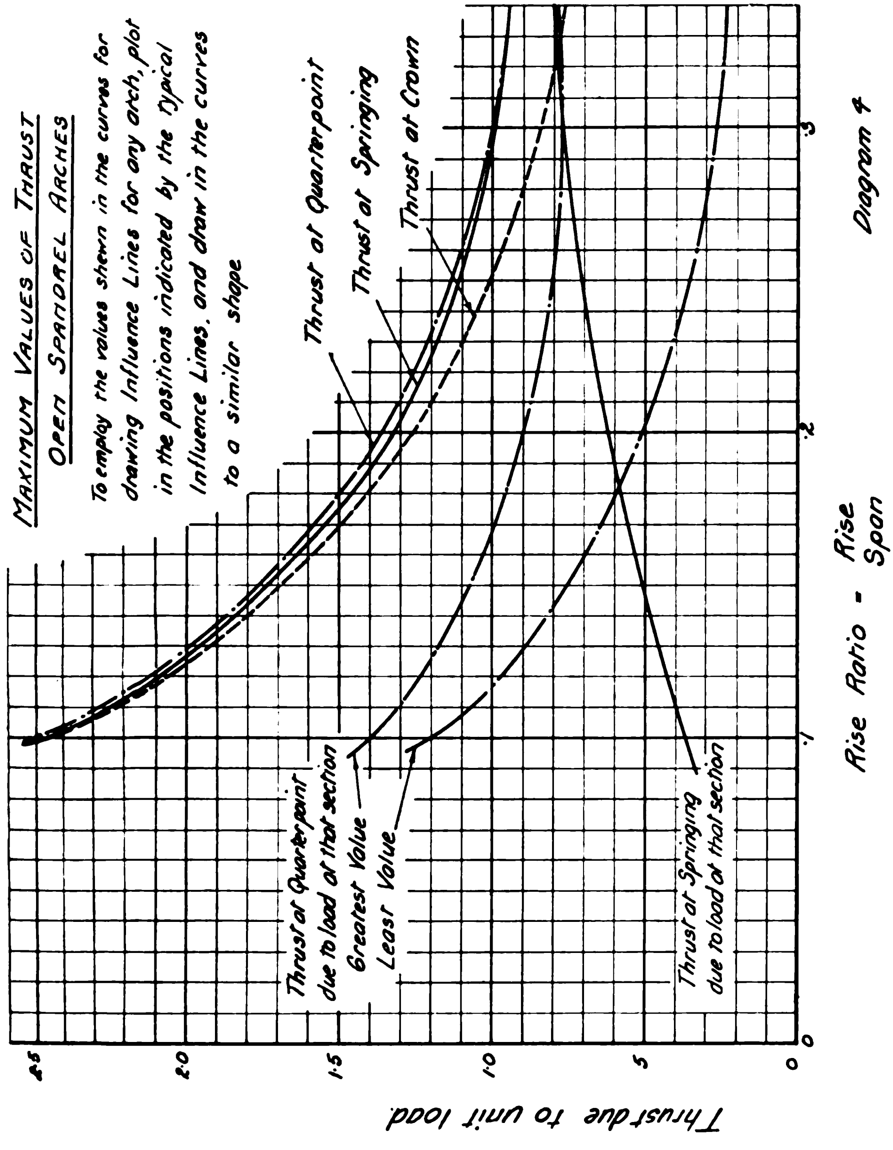


Diagram 3

THE DESIGN OF REINFORCED CONCRETE ARCH RIBS. (*See p.* 143.)

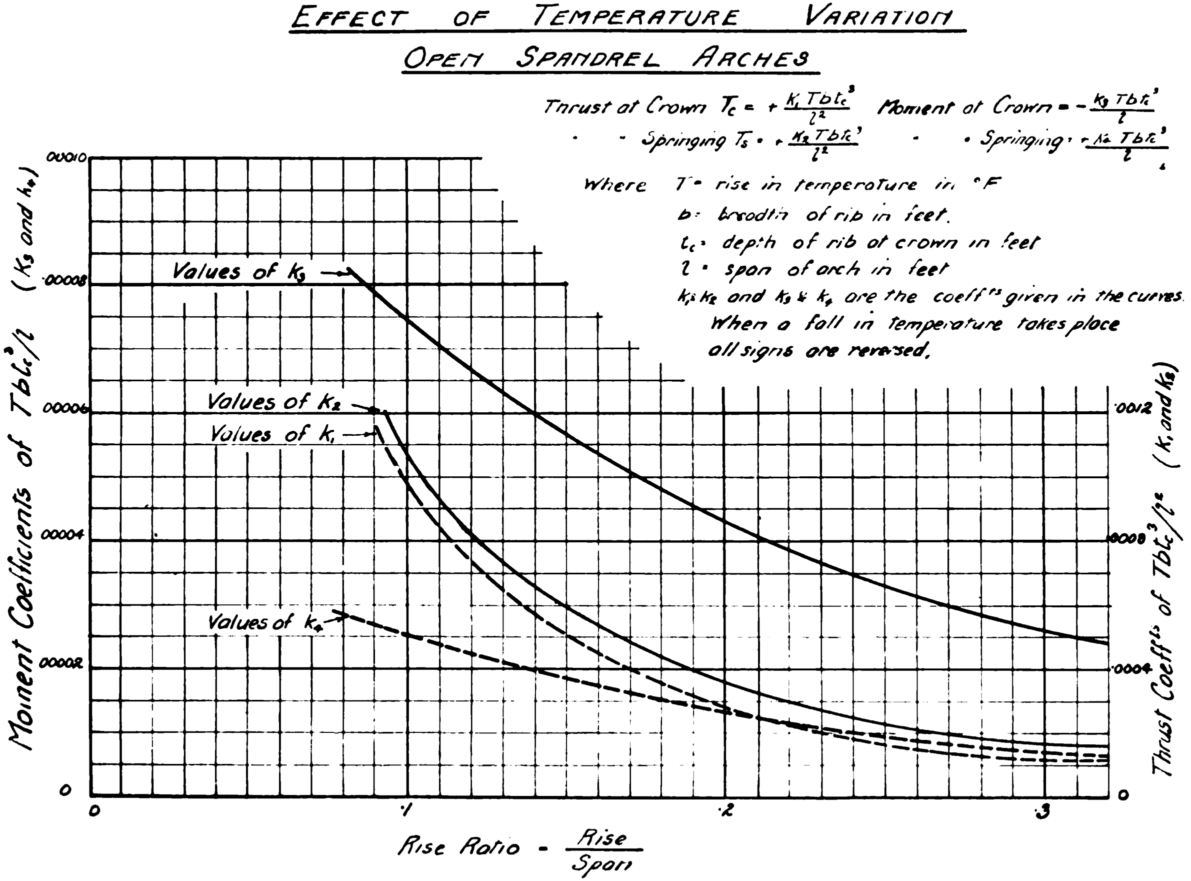


MAXIMUM VALUES OF THRUST

OPEN SPANDREL ARCHES

To employ the values shewn in the curves for drawing Influence Lines for any arch, plot in the positions indicated by the typical Influence Lines, and draw in the curves to a similar shape

THE DESIGN OF REINFORCED CONCRETE ARCH RIBS. (See p. 143.)



EFFECT OF TEMPERATURE VARIATION

OPEN SPANDREL ARCHES

Thrust at Crown $T_c = +\frac{K_1 T b t_c^3}{l^2}$ Moment at Crown $= -\frac{K_3 T b t_c^3}{l}$

" " Springing $T_s = +\frac{K_2 T b t_c^3}{l^2}$ " " Springing $= +\frac{K_4 T b t_c^3}{l}$.

Where T = rise in temperature in °F

b = breadth of rib in feet.

t_c = depth of rib at crown in feet

l = span of arch in feet

k_1 k_2 and k_3 & k_4 are the coeff^ts given in the curves.

When a fall in temperature takes place all signs are reversed.

Values of K_3
Values of K_2
Values of K_1
Values of K_4
Moment Coefficients of Tbt_c^3/l (K_3 and K_4)
·00010
·00008
·00006
·00004
·00002
0
Thrust Coeff^ts of Tbt_c^3/l^2 (K_1 and K_2)
·0012
·0008
·0004
0
0
·1
·2
·3
Rise Ratio = $\frac{Rise}{Span}$

Diagram 5

THE DESIGN OF REINFORCED CONCRETE ARCH RIBS. (See p. 143.)

THE MENIN GATE MEMORIAL.

On the following page we illustrate a perspective of the Menin Gate Memorial, of which Sir Reginald Blomfield, R.A., is the architect. The following particulars regarding the foundations of the memorial, together with the working drawings, have been supplied by Dr. Oscar Faber, O.B.E., D.Sc., consulting engineer for the work :—

The difficulty with regard to the Menin Gate from an engineering point of view was the nature of the foundations. A trial hole revealed the fact that the soil consisted, on the average, of the following formation :—The top 4 ft. black loam and ashes, below that yellow and grey clay and sand extending down to blue clay, which was found at a depth of about 27 ft.

This yellow and grey clay is entirely waterlogged from a distance of about 12 ft. downwards and behaves practically as a quicksand under certain conditions. So treacherous is it that a trial hole 12 ft. by 8 ft., in which the sides consisted of sheet piling extending down for a distance of 35 ft., was found almost impossible to excavate as the quicksand leaked through between joints in the piling and the bottom rose at night as rapidly as the excavators were able to deal with it in the daytime. It was found impossible to drive an excavation with runners more than 12 ft. deep for the same reason, namely, that the bottom kept blowing upwards.

The original design for the foundations consisted of hollow concrete foundations more or less in accordance with the section on *Fig.* 1, and alternative designs were considered for this box foundation in plain concrete and in reinforced concrete, the drawing shown in *Fig.* 1 being actually that for plain concrete. After the result of the trial hole above referred to it was, however, found possible to avoid the difficulties of this excavation by constructing a reinforced concrete raft just below road level and supporting this on reinforced concrete piles 40 ft. long, 16 in. square. These piles extend a matter of 16 ft. into the blue clay and carry on an average about 30 tons each. Those at the sides of the foundations are raking so as to deal with the horizontal thrust due to the arch in one direction and to the pressure of the earth from the ramparts in the other. These two pressures tend, of course, to counteract each other, but it was impossible to estimate their magnitude without a risk of error and therefore some provision was made to deal with a horizontal thrust in either direction. The general arrangement of the piling is shown in *Fig.* 2 (pp. 154–5).

The whole of the superstructure also consists of reinforced concrete clothed in stone on the exposed surfaces, except in the case of the soffit to the arch and the floors over the loggias, etc., where the reinforced concrete will be visible.

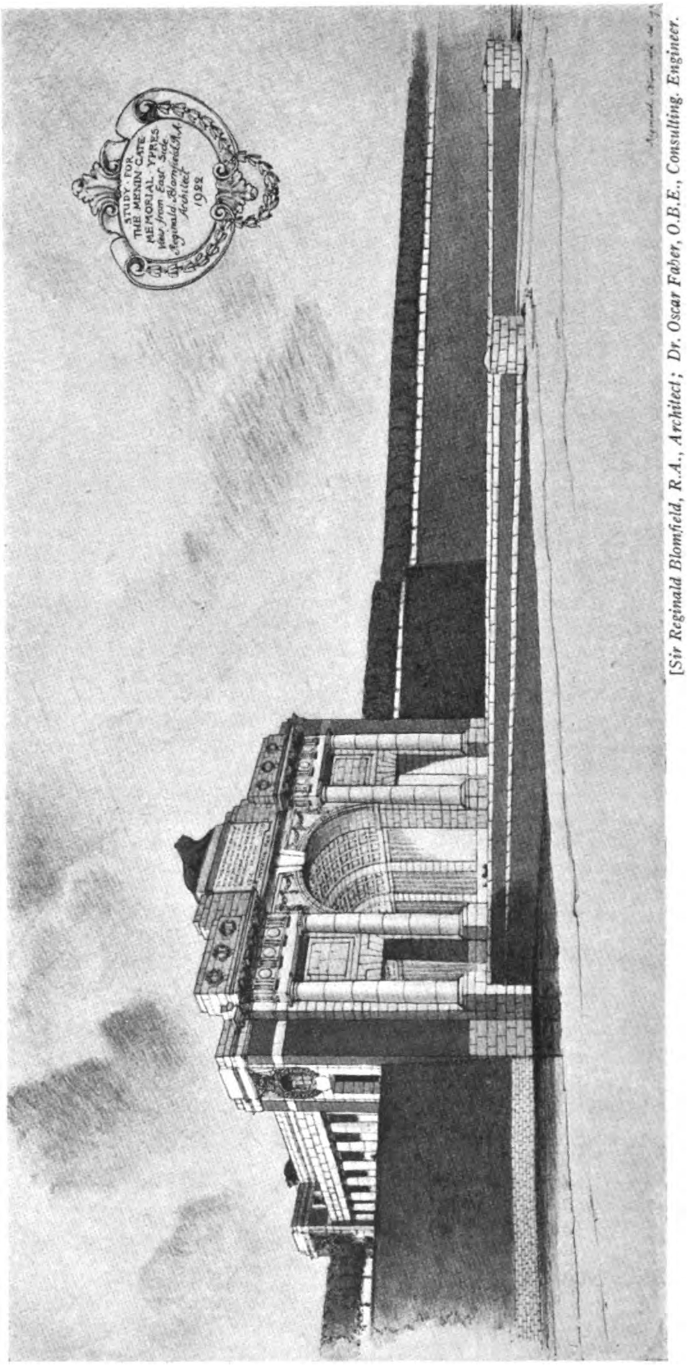
The main arch and the loggias have a coffered soffit which is to be constructed by casting it direct in specially prepared moulds. *Fig.* 3 (pp. 170–1) and *Fig.* 4 (pp. 186–7) indicate this coffering, and the general nature of the reinforcement, both in the arch and in some of the vertical and horizontal members of the abutments.

In the calculations for the arch, the stresses due to variations of temperature received careful attention, and the whole structure was designed with a view to permanence, which explains why some of the provisions shown in the figures indicate rather better protection against the effect of stress and weather than might be necessary in a structure of a more temporary nature.

The concrete is to be composed of granite and Rhine sand, and the steel is to be British Standard Specification, although this is, perhaps, unusual in Belgium, the Belgian specification being considerably lower than ours in regard to mild steel.

An interesting feature of the site is the old brick walls to the ramparts, which, as many of your readers will know, project to a considerable height above the road on each side of it. What was perhaps not so well known was that these rampart walls continued across the road below ground right down to and into the blue clay. These walls are very massive, and were probably designed to resist artillery fire in oldtime warfare just as much as to act as efficient retaining walls to the earth forming the ramparts.

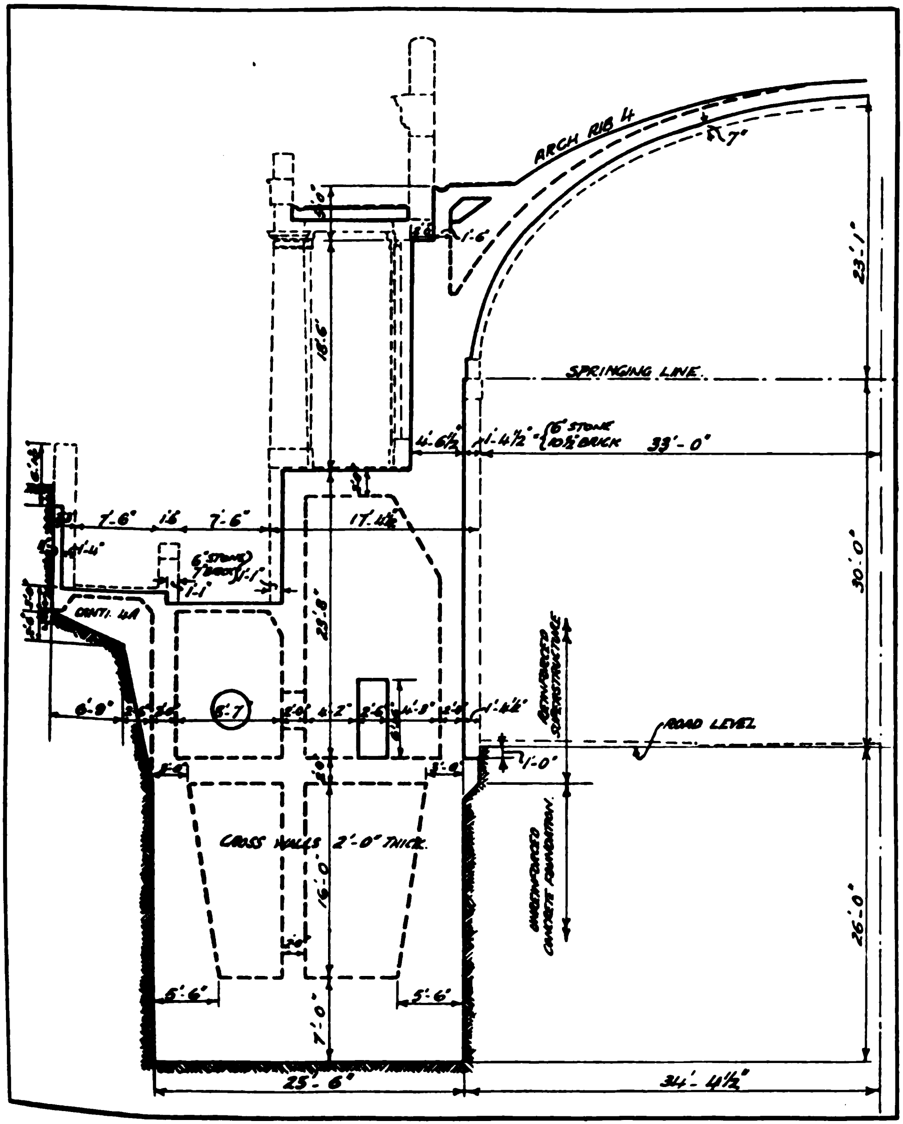
These walls at road level are approxim-



[Sir Reginald Blomfield, R.A., Architect; Dr. Oscar Faber, O.B.E., Consulting. Engineer.

THE MENIN GATE MEMORIAL.

ately 10 ft. thick, but are stiffened by massive buttresses at the back of the wall at approximately 16 ft. centres, the total width of the wall at ground level to the back of the buttress being approximately 20 ft. The front of the wall has a batter of approximately 1 in 5 extending right down to the foundations, so that at a depth of about 27 ft. below the road where the walls are founded the overall width over the buttresses is about 25 ft., of which the wall itself amounts to about 15 ft. It is found that this massive brickwork construction crosses the rafts forming the foundations of the new Menin Gate, and after careful examination and repair this brick structure has been taken advantage of for supporting that portion of the raft which comes immediately upon it.



[*Sir Reginald Blomfield, R.A., Architect; Dr. Oscar Faber, O.B.E., Consulting Engineer.*

FIG. 1.—FOUNDATIONS OF THE MENIN GATE MEMORIAL.

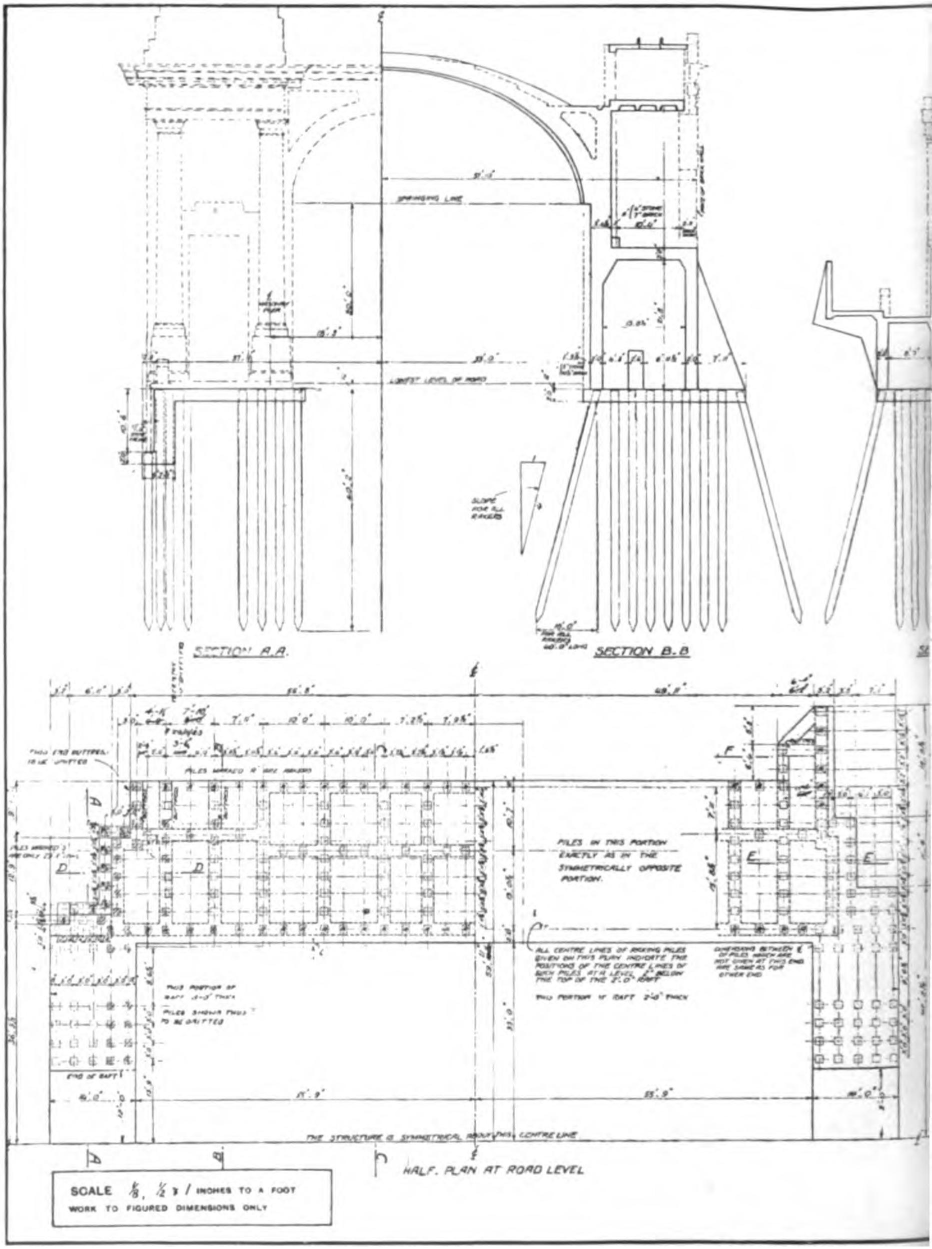
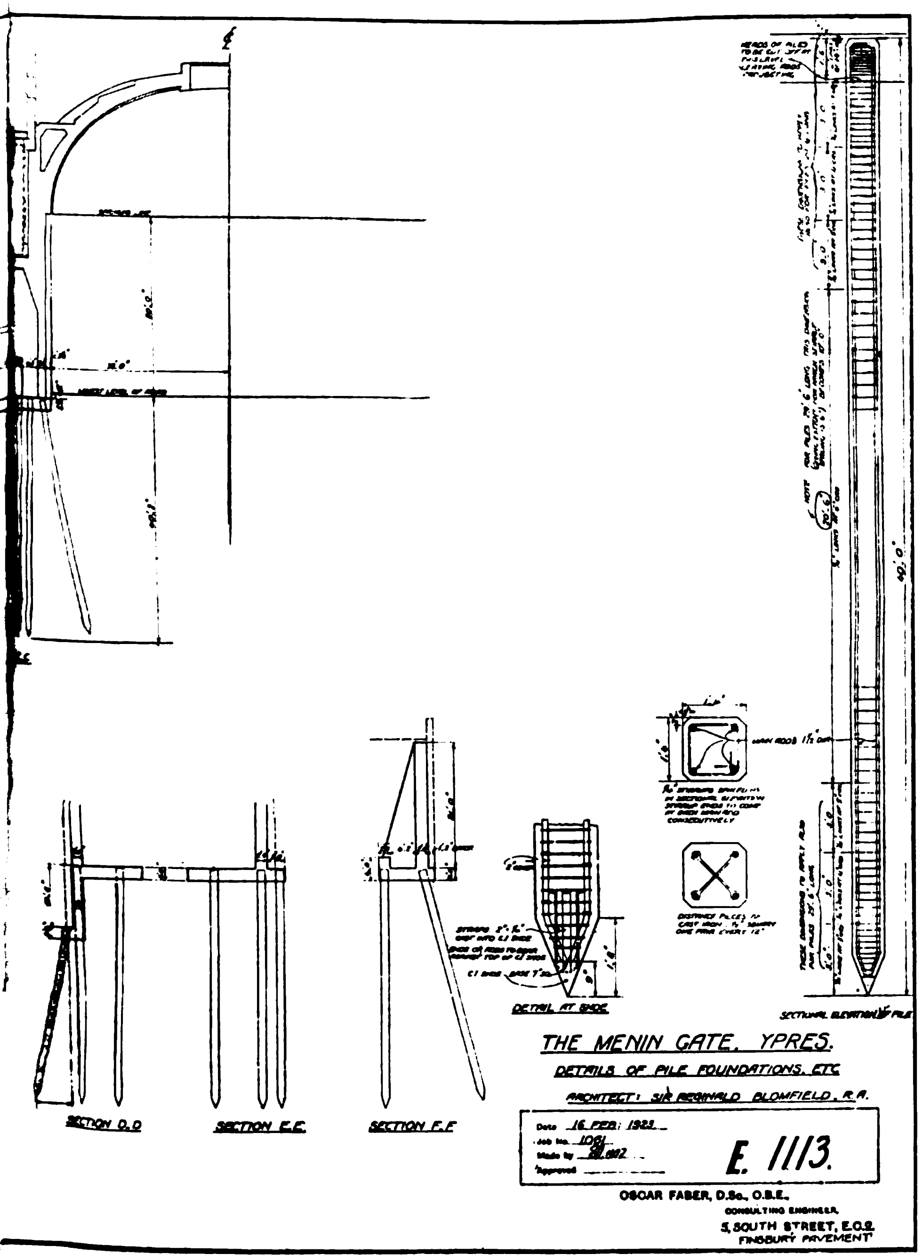

SPRINGING LINE
LOWEST LEVEL OF ROAD
SLOPE FOR ALL RAKERS
SECTION A.A.
SECTION B.B
PILES MARKED 'R' ARE RAKERS
THIS END BUTTRESS TO BE OMITTED
PILES IN THIS PORTION EXACTLY AS IN THE SYMMETRICALLY OPPOSITE PORTION.
ALL CENTRE LINES OF RAKING PILES GIVEN ON THIS PLAN INDICATE THE POSITIONS OF THE CENTRE LINES OF SUCH PILES AT A LEVEL 2" BELOW THE TOP OF THE 2'.0" RAFT
THIS PORTION OF RAFT 2'-0" THICK
DIMENSIONS BETWEEN ℄ OF PILES WHICH ARE NOT GIVEN AT THIS END ARE SAME AS FOR OTHER END
THIS PORTION OF RAFT 2'-0" THICK
PILES SHOWN THUS TO BE OMITTED
END OF RAFT
THE STRUCTURE IS SYMMETRICAL ABOUT THIS CENTRE LINE
A
B
C
D
E
F
HALF. PLAN AT ROAD LEVEL
SCALE ⅛, ½ & 1 INCHES TO A FOOT
WORK TO FIGURED DIMENSIONS ONLY

FIG. 2.—FOUNDATIONS OF THE



Sir Reginald Blomfield, R.A., Architect; Dr. Oscar Faber, O.B.E., Consulting Engineer.

N GATE MEMORIAL. (*See p.* 151.)

REINFORCED CONCRETE AND FIRE-RESISTANCE.

VII. ADDITIONAL DATA AND GENERAL CONCLUSIONS.

By **J. SINGLETON-GREEN, B.Sc. (Hons.), A.M.I.Struct.E., M.Am.C.I.**

(*Concluded from April,* 1923.)

It is proposed in this article to give in a brief form conclusions derived from the previous articles, together with any additional data which have come to the notice of the writer since the first six articles were written.

CONCLUSION 1.

There is no such thing as a " fireproof " building. Every building (whatever its nature or construction) has a certain " fire-resisting " capacity—the question is one of degree.

It has been suggested that it is clearly possible to construct a building so that it would successfully withstand any number of fires without any more serious result than damage to the windows and decoration. This is true when dealing with ordinary fires, but whatever the nature of the building a fire could be " found " which would cause failure, and the above conclusion remains essentially true. The question is finally settled, of course, by personal inclinations, available funds, and the exercise of reasonable caution.

CONCLUSION 2.

Reinforced concrete is the best form of fire-resisting construction of which we know at present. The fire-resistance, however, can be of varying degrees depending on numerous factors.

CONCLUSION 3.

Insurance companies should vary their rates of insurance for reinforced concrete buildings according to the nature of the design and the method of construction. This calls for joint action between architects, engineers and insurance companies; and the writer ventures to suggest that this is a work which could be inaugurated by one of the professional institutions. The results obtained should be exceedingly valuable. Until this is done there will be little incentive for owner-builders to spend more on a building than is necessary in order to make it comply with the present regulations, since they would not be able to claim any allowance in the insurance rates. This is a state of affairs which should be remedied as soon as possible.

Many advantages would accrue from a sliding insurance scale. First, there would be a saving of premiums, a fact which is borne out by Mr. Humphrey in his paper read before the Concrete Institute,[1] where he states that in an investigation of the various concrete buildings erected in America [paper read in 1911] the owners of 26·6 per cent. of the buildings reported that they carried no insurance on the buildings themselves, but merely insured the contents, some not even the latter.

The reduced rates for better fire-resisting buildings would probably more than balance the increased cost of construction. In this connection it is interesting to note that in February, 1915, Mr. A. A. H. Scott read a paper before the Society of Architects on the " Construction and Protection of Buildings against Fire,"[2] wherein he suggested that it would be advisable for all by-laws to make it compulsory that *all* external walls and internal partitions and floors be constructed of fire-resisting material. It is pointed out that the expense would not be quite so drastic as one would think, and prices are given in illustration. To-day's prices will, of course, be different, but the ratios of Mr. Scott's prices are as follows:

FLOORS—

	Per ft. sup. pence.
Wooden floors suitable for domestic buildings taken in spans of 12 ft.	1
Fire-resisting floor, ditto . .	1·53
Wooden floors for workshop at 200 lbs. super load per sq. ft. Spans 10 ft.	1
Ditto, ditto, Fire-resisting floors	1·19
(Basis of last two items taken for floor 30 ft. by 100 ft.)	

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[1] Fire-proofing—Concrete Institute, October, 1911.

[2] Abstract (part), *Concrete and Constructional Engineering*, Vol. 10, No. 3, 1915.

	Per yd. sup. pence.
Cost of wood-framed partition, plastered on both sides . .	1
Cost of fire-resisting partition, plastered on both sides . .	1
Cost of fire-resisting partition, plastered on both sides . .	0·99

The units in each case are, of course, not the same.

Again, the sliding scale would encourage the construction of buildings of high fire-resistance. This is all to the public good, for it should be realised that fire loss is a national loss, paid by the public, and not by the fire-insurance companies.[1] The extent of this fire loss may be appreciated when it is pointed out that property valued at $230,000,000 was destroyed by fire in America during the first seven months of 1922.[2]

The question of dwelling-houses built of concrete, in this connection, is one which cannot be dealt with here, but the subject is thoroughly discussed in the Editorial Notes in *Concrete and Constructional Engineering*, Vol. 15, No. 7 (1920); see also paper on "Reinforced Concrete Fireproof Construction Applied to Home Building," by P. J. Hueber, in the *Proceedings* of the American Concrete Institute, Vol. 18, page 162 (1922).

CONCLUSION 4.

It is absolutely necessary to have continuous competent supervision of reinforced concrete buildings during erection to ensure that all details are properly carried out: then adequate guarantees could be given to the insurance companies.

CONCLUSION 5.

The insurance regulations for reinforced concrete construction which are in force at the present time do not give any encouragement for improving the fire resistance of reinforced concrete work.

CONCLUSION 6.

In addition to insurance, supervision, and joint action, further research is needed.

CONCLUSION 7.

In Professor Lea's tests on mild steel it is found that both the yield stress and the breaking stress of the steel reach the design working stress of 7 tons per sq. in. at a temperature very little more than 600° C., and there seems to be no doubt that if the beams and slabs are fully loaded failure is bound to take place when the steel reaches a temperature approximating to 650° C.

Since writing the article relating to the above, further information has come to the writer's notice. As the results are of recent date it is thought that their inclusion here will be advantageous, especially as they are in general agreement with those previously reported.

COMPARATIVE TESTS OF STEELS AT HIGH TEMPERATURES. By R. S. MACPHERRAN.—Results of experiments on the determination of properties of steels at high temperatures were given in a paper read at the A.S.T.M., June 24, 1921, and reported in *Chemical and Metallurgical Eng.*[1]

The following results are to be noticed:

(1) In all steels treated there is a definite falling off in tensile strength after about 300° C., and this is more or less rapid according to the composition.

(2) The results indicate that the introduction of metals forming carbides tends to strengthen steels at high temperatures.

STRENGTH AND ELASTICITY OF BOILER PLATES AT ELEVATED TEMPERATURES.[2] BY A. J. FRENCH.—In this article original experiments on boiler plates are reported in addition to previous work by other people. The results of Huntington,[3] Epps and Jones,[4] and Howard,[5] as well as those obtained by French, show a rapid decrease in the tensile strength of wrought iron and steel after passing about 300° C.

All these results are in accordance with Dr. Lea's work.

EFFECT OF TEMPERATURE ON THE MECHANICAL AND MICROSCOPIC PROPERTIES OF STEEL.[6] BY G. C. PRIESTER AND O. E. HARDER.—Tests were made on hardened 0·16 per cent. carbon steel to determine the maximum stress, yield

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[1] See Editorial in *Engineering News-Record*, Vol. 89, No. 3.

[2] See Editorial in *Concrete*, U.S.A., November, 1922.

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[1] *Chem. and Met. Eng.*, Vol. 24, No. 26, p. 1153 (1921).

[2] *Chem. and Met. Eng.*, Vol. 26, No. 26, p. 1207 (1922).

[3] *J. Inst. Met.*, p. 126 (1912).

[4] *Chem. and Met. Eng.*, Vol. 17, p. 67 (1917).

[5] *Iron Age*, Vol. 45, p. 585 (1890).

[6] *Chem. and Met. Eng.*, Vol. 28, No. 3, p. 111 (1923).

point, etc., at temperatures from 20°–600° C.

Hot-rolled steel ¾ in. diameter was used of the following composition :—

C.	0·16
Mn.	0·46
S.	·034
P.	·009

The test pieces were machined, heated to 910° C., held for one hour, cooled slowly in the furnace, re-heated to 910° C., held for 30 mins., then quenched in water. Specimens were then heated to various temperatures, held there for ½ hour and tested.

The conclusion drawn from these tests which is of importance to our subject is that above about 300° C. the maximum stress and yield point decrease almost as a straight line function of the temperature and the effect on the maximum stress is the most pronounced.

Generally, the curves are similar to those obtained by Professor Lea.

It will be noticed that all this additional evidence strengthens the original statement, so that we are quite safe in drawing the following conclusion.

CONCLUSION 8.

If the temperature of mild steel reaches 600°–650° C. the (so-called) factor of safety of four (under full load) becomes a factor of safety of one. If secondary stresses are not taken into account at all, then failure will occur sooner. We shall be well on the way to safety if we can keep the steel temperature below 600° C., and at the same time allow for as many secondary stresses as possible in the design.

CONCLUSION 9.

An endeavour should be made, therefore, to obtain a covering for beams, slabs, and columns that will not readily crack, and is such a bad conductor that it will prevent the steel from reaching the dangerous temperature ; or, alternatively, to find other means for keeping the reinforcement cool in case of fire.

CONCLUSION 10.

Aggregates containing high percentages of silica cannot be considered as first-class fire-resisting materials. Spalling can be prevented in some measure by the use of wire ties to hold in the concrete, but even then there is further danger as the temperature rises. Even at low temperatures the unequal expansion of quartz in different directions makes the material unreliable.

CONCLUSION 11.

Flint as an aggregate or a constituent of an aggregate is capable of even less fire resistance than quartz.

CONCLUSION 12.

As most British gravels contain flint, quartz, or quartz-bearing rocks as their chief ingredients, it is advisable to ascertain whether it would not be possible still to use these gravels if protected by coverings possessing greater fire-resistance.

CONCLUSION 13.

It follows from the above that granite and sandstone are not suitable aggregates to use for reinforced concrete construction if a high degree of fire-resistance is required.

CONCLUSION 14.

Dolerite and basalt appear to be better than granite.

Unfortunately, lack of space prevents further notes on the various aggregates in general use, although it should be mentioned that much research still needs to be done.

However, to convey a general impression of the comparative values of certain aggregates, the table on next page is given by kind permission.[1]

Tests made by the British Fire Prevention Committee[2] give some idea of the relative values of various aggregates. The following summary can be compared with previous information.

PLAIN CONCRETE SLABS : NATURAL AGGREGATES.

(1) Thames ballast, or any flint aggregate, proved unsatisfactory from a fire resistance standpoint.

(2) Gravels and sandstones were also unsatisfactory.

(3) Limestones showed somewhat better results.

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[1] Experiments conducted at the Underwriters' Laboratories, Chicago, Illinois, 1917–1919.

[2] See Paper by D. W. Wood, Junior Inst. of Engs., *Journal and Record of Trans.*, Vol. 31, Part 10, July, 1921.

FIRE-RESISTANCE PERIODS DERIVED FROM THE TEST RESULTS.

Type of Column.	Protection Material.	Nominal Thickness of Protection.	Fire-Resistance Period.
		Inches.	Hours.
Structural Steel	Concrete: siliceous gravel aggregate .	2	1
Do.	Ditto	4	2½
Do.	Concrete; granite, sandstone or hard coal cinder aggregate		2½
Do.	Ditto	3	3½
Do.	Ditto	4	5
Do.	Concrete; trap rock aggregate . . .	2	3
Do.	Ditto	3	4
Do.	Ditto	4	5
Do.	Concrete; limestone or calcareous gravel aggregate .	2	4
Do.	Ditto	3	6
Do.	Ditto	4	8
Round Cast Iron	Concrete; trap rock granite, or hard coal cinder aggregate . . .	2	2
Reinforced Concrete	Limestone or calcareous gravel concrete. . . .	2	8
Do.	Trap rock concrete .	2	5

(4) Igneous rocks were generally poor, Nottingham basalt proving the best, with trachyte next. Granites did not behave well.

PLAIN CONCRETE SLABS: ARTIFICIAL AGGREGATES.

(5) Slags behaved well.

(6) Bricks (thoroughly cleaned) prove to be the best.

(7) Fire brick stood well.

(8) Burnt gault clay (Burnham, Kent), like bricks, gave good results.

(9) Coke breeze (which, by the way, contained as much as 6 per cent. by weight of unburnt coal) proved satisfactory, especially with fine breeze in lieu of sand.

(10) Pan breeze clinker also gave good results.

REINFORCED CONCRETE SLABS: NATURAL AGGREGATES.

(1) As in the case of plain concrete, the different aggregates described above gave similar results.

REINFORCED CONCRETE SLABS: ARTIFICIAL AGGREGATES.

(2) The coke breeze and pan breeze were not so successful as in the plain concrete cases.

(3) Brick proved, on the whole, most successful—as with the plain concrete; also burnt gault clay, mixed with its own fine stuff.

CONCLUSION 15.

Although the question of the strength of concrete after heating is of the utmost importance, there does not appear to be sufficient information available to form a definite table giving quantitative values.

To the tests reported in Article 5 of this series can be added results obtained by Mr. W. A. Hull on Fire Tests of Concrete Columns.[1] The reader is referred to the previous numbers of *Concrete and Constructional Engineering* mentioned in the footnote.[1]

CONCLUSION 16.

Even if the concrete is capable of keeping in place and acting as a protection to the steel, it is quite possible that the steel may reach the dangerous temperature owing to the conduction of heat through the protecting coat.

CONCLUSION 17.

There does not appear to be a great amount of difference in the conductivities of concretes made with different aggregates, unless materials are used which change chemically below 650° C.

CONCLUSION 18.

In B.F.P.C. *Red Book* No. 252 the following approximate rule is given for the temperature distribution in the lower 2 in. of slabs when their lower surfaces have been exposed to fire for two to four hours.

"Deduct from the temperature of the flames in contact with the surface 300° F. (148·8° C.) for ½ in. (0·013 m.), 500 ° F. (260·0° C.), for 1 in. (0·025 m.), and 900° F. (482·2° C.), for 2 in. (0·051 m.) within the slab."

The temperatures are approximately 100° F. (37·7° C.) higher in slabs composed of flint or certain types of clinker and coke breeze, and lower in slabs composed of limestone or burnt Gault clay.

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[1] Original paper in the *Proceedings* of the American Concrete Institute, Vol. 16, p. 20, 1920. Reported in *C. & C.E.*, Vol. 15, Nos. 3 and 4, 1920; and in *Concrete*, U.S.A., April, 1920.

CONCLUSION 19.

When beams and columns cannot be rounded sufficiently to avoid spalling some form of mesh reinforcement should be used to tie in the concrete. Special precautions of this nature should always be taken when siliceous aggregates are used. The increase in safety outweighs the slight increase in cost. There is a great diversity of opinion as to whether or not a round column is better than a square one. There is expert opinion on both sides, but until more definite information is available, the writer feels inclined to give preference to the round column.

CONCLUSION 20.

Construction joints are a source of weakness, and special care should be taken with them.

CONCLUSION 21.

If the surface finish to a floor is laid after the slab has hardened this will be a source of weakness, as there is always a tendency (accentuated by fire) for the surfacing to break away from the slab proper. Wherever possible, then, the finish should be laid at the same time as the rest of the floor. This, of course, is an advantage from the design point of view.

CONCLUSION 22.

The construction of reliable waterproof floors is important, as not infrequently the water damage is far in excess of the fire damage. This is illogical and unnecessary.

CONCLUSION 23.

Fire-resisting partitions should be built to break up large floor areas. Unbroken floor areas should not exceed a certain definite size, the actual figure in any particular instance depending on the nature of the building and the contents. A compartment 150 ft. by 150 ft. is probably the maximum size consistent with reasonable safety.

CONCLUSION 24.

If a high degree of fire-resistance is to be obtained good supervision is essential. It is hardly necessary to say that if the steel is not bent up correctly over the supports, or if shear steel is lacking, then the factor of safety is immediately seriously reduced. Failure is occasionally due to faulty design; more often to bad workmanship. Both these faults can be remedied.

Mixing of the concrete is important: The aggregates must be correctly graded and the mixing must be thorough.

CONCLUSION 25.

All openings in a building must be fully protected (this applies to any kind of construction). Even small openings are dangerous.

CONCLUSION 26.

The height of buildings should be limited to correspond to the degree of protection which the building equipment and the fire department are able to furnish (this applies to any kind of construction).

CONCLUSION 27.

Where necessary, buildings should have an efficient equipment of automatic sprinklers (this again applies to any kind of construction), unless contents are highly damageable.

CONCLUSION 28.

Safety devices need close attention.

An important item under the heading " Structural Details " not yet dealt with is the question of fire-escapes, chutes, etc. Technically it might be said this is not a matter for the reinforced concrete engineer, but it is of such importance that a brief outline of the main features is here given. For fuller details the reader is referred to the paper on " Fireproofing," by R. L. Humphrey, from which much of the following information is abstracted.

Safety appliances and facilities for escape may be discussed under the following headings :—

(1) Iron fire-escapes.

(2) Encased stairways and stairway towers.

(3) Encased fire-towers.

(4) Spiral chutes.

IRON FIRE-ESCAPES.—These are almost, if not utterly, useless owing to the peculiar manner in which they are built—steep iron ladders with narrow treads are not conducive to rapid action even under normal conditions.

Again, when the heat reaches one of these escapes it soon becomes a crumpled wreckage of ironwork. Mr. Humphrey suggests that such contrivances should be made criminal.

ENCASED STAIRWAYS AND STAIRWAY TOWERS.—As often constructed these serve as a medium for carrying the fire from floor to floor. They should be protected at all floors by adequate fire-resisting partitions.

ENCASED FIRE-TOWERS.—These are usually enclosed by fire-resisting walls, and in this respect are good. If the approach to the tower is through an open-air vestibule having fire-resisting doors at each end this method is quite good, and is the one which should be developed to the utmost extent by designers. Exits, however, should be numerous; a single fire-tower, and hence one flight of steps, is not sufficient to empty several large floors of a building at one time.

SPIRAL CHUTES.—These are good when properly designed and they have the added benefit of being pleasure-giving during fire-practice, a point of no small value.

GENERAL CONCLUSION.

Many points require further research, and several questions remain unanswered. For instance :—

(1) What are the fire-resisting properties of mixtures of aggregates, both natural and artificial, e.g. basalt and brick ?

(2) What happens exactly to high-tension steel and high-carbon steel in a fire ?

(3) What is the best classification to adopt for aggregates ?

(4) What are the fusion temperatures of various concretes ?

It is pleasing to note that great strides are being made in the subject every year, as important experiments are being carried out in many countries. It is singularly fortunate that whilst American experimenters have devoted themselves mainly to columns, the English tests have dealt chiefly with slabs; and to complete the series reinforced concrete houses were tested in Germany.

The subject of reinforced concrete and fire-resistance is such a large one that it has been impossible to cover the entire ground in these seven articles. Many subjects remain to be considered, the chief of which are the fire-resistance of concrete blocks and bricks and reinforced concrete chimney linings; and it is hoped to deal with these in the near future.

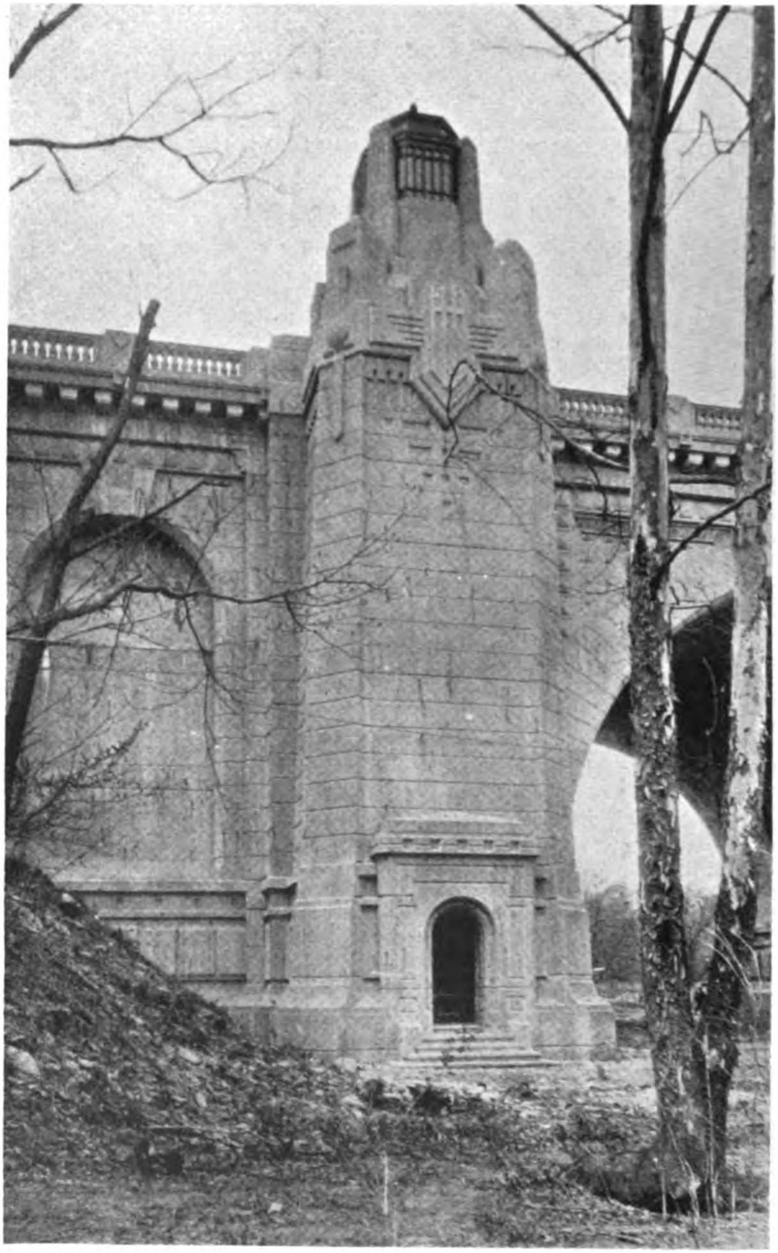
Acknowledgment is due to Dr. Oscar Faber for much valuable help and guidance. The writer also wishes to thank Mr. L. W. Dodson for his assistance with the diagrams.

APPENDIX.

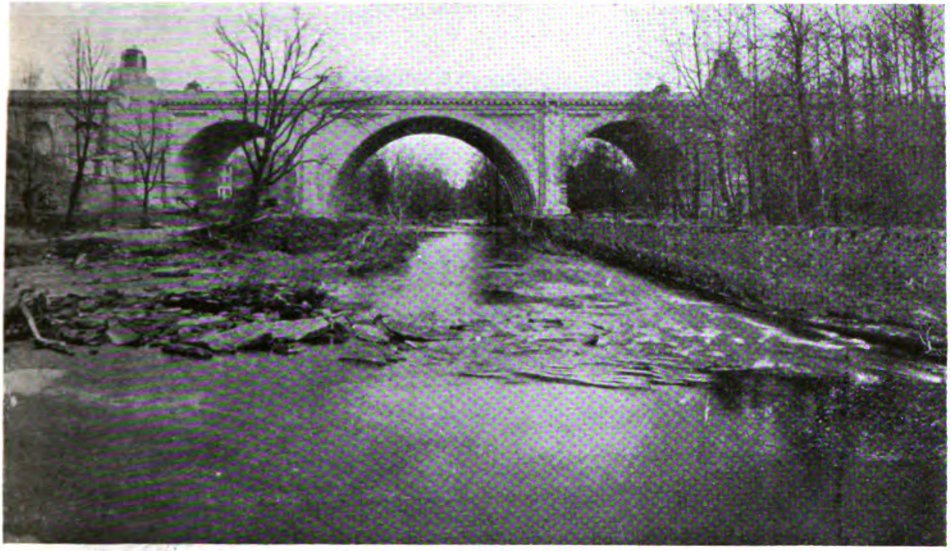
"PORETE."—"Porete" is the name of a new fire-resisting building material made in America in slab form as a sheathing material, and base for stucco as a sheathing on steel-frame buildings, for fire-stops, roof-decks and inside furring. "Porete" is said to be made of Portland cement and sand; it has the appearance of pumice, excepting only that the bubble-holes are larger, somewhat like a rubber sponge. It is not announced how the porous characteristics are obtained, but the original mixture of sand and cement is said to contain some other material which, after partial curing of the concrete, becomes gaseous under the application of heat and passes off, leaving the holes. The material is made in thin slabs for the different purposes mentioned, and at 1 in. thick weighs only 5 lb. per sq. ft.

In a severe fire at Newark, N.J., U.S.A., a "porete" partition showed up well. An examination of this partition (consisting of 1 in. thick "Porete" slabs nailed to a 1 in. wood partition or to a 2 in. by 4 in. wood framework, the whole covered with a ¼ in. thick plaster coat) disclosed the fact that the ¼ in. plaster finish was cracked in many places and had been washed down by the water. The "porete" slabs, however, although much scorched, were intact. Near the northern end, where the fire was hottest, the cement structure of the "Porete" slabs was dried out to a depth of ⅛ in. to ¼ in., but the cement was hard and solid and the dehydrated layer protected the "porete" behind it.

It was evident from this fire that "porete" had successfully prevented the fire from spreading to the adjoining room. The result confirmed what had been found by preliminary fire tests which were made in January, 1921, at the laboratories of the National Board of Fire Underwriters in Chicago, Illinois. "Porete" siding slabs 1 in. thick will successfully withstand 1700° F. for a very long time. At the test in Chicago it was found that after 1½ hours of fire the slabs were only slightly warped and would have stood up considerably longer.



CONCRETE BRIDGE IN PHILADELPHIA: ONE OF THE FOUR PYLONS. (*See p.* 163.)



Concrete Bridge in Philadelphia.

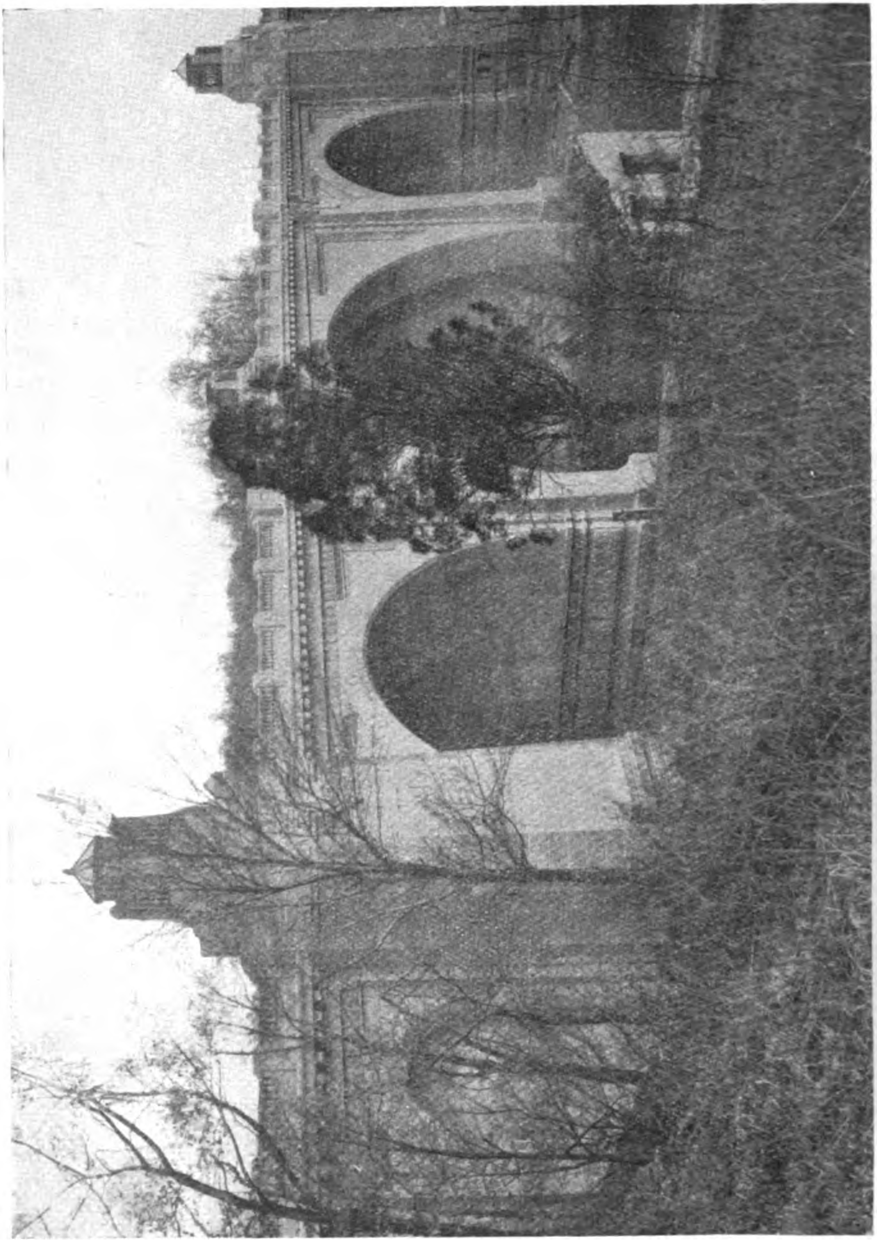
CONCRETE BRIDGE IN PHILADELPHIA.

The bridge over Pennypack Creek, Philadelphia, is particularly notable for its architectural design and ornamentation. The main ornamental details are four large pylons between the 60-ft. arches and wing walls, which extend from the creek level to 25 ft. above the sidewalk level of the bridge. The top of each pylon is formed into a lantern with ornamental ironwork with orange-coloured glass. A stairway connects a guard room in the pylons at both street levels, and entrance from the street is through a heavy oak door studded with iron. Pylons of a lighter design are placed at the abutments of the main central arch.

The moulding of the concrete for this bridge required some interesting formwork, and the greatest care was used in pouring and finishing.

Except the railing, which was pre-cast, all the concrete ornament was built monolithic with the mass concrete.

The total length of the bridge is 585 ft., with a central arch of 100 ft. and two approach arches of 60-ft. span. The width of the bridge is 78 ft., with 54 ft. devoted to a roadway and two 8-ft. sidewalks with intermediate strips of grass lawn 4 ft. in width. The hand rail is 69 ft. above the bed of the creek.



CONCRETE BRIDGE IN PHILADELPHIA. (*See p.* 163.)

WIDEST CONCRETE STREET IN AMERICA.

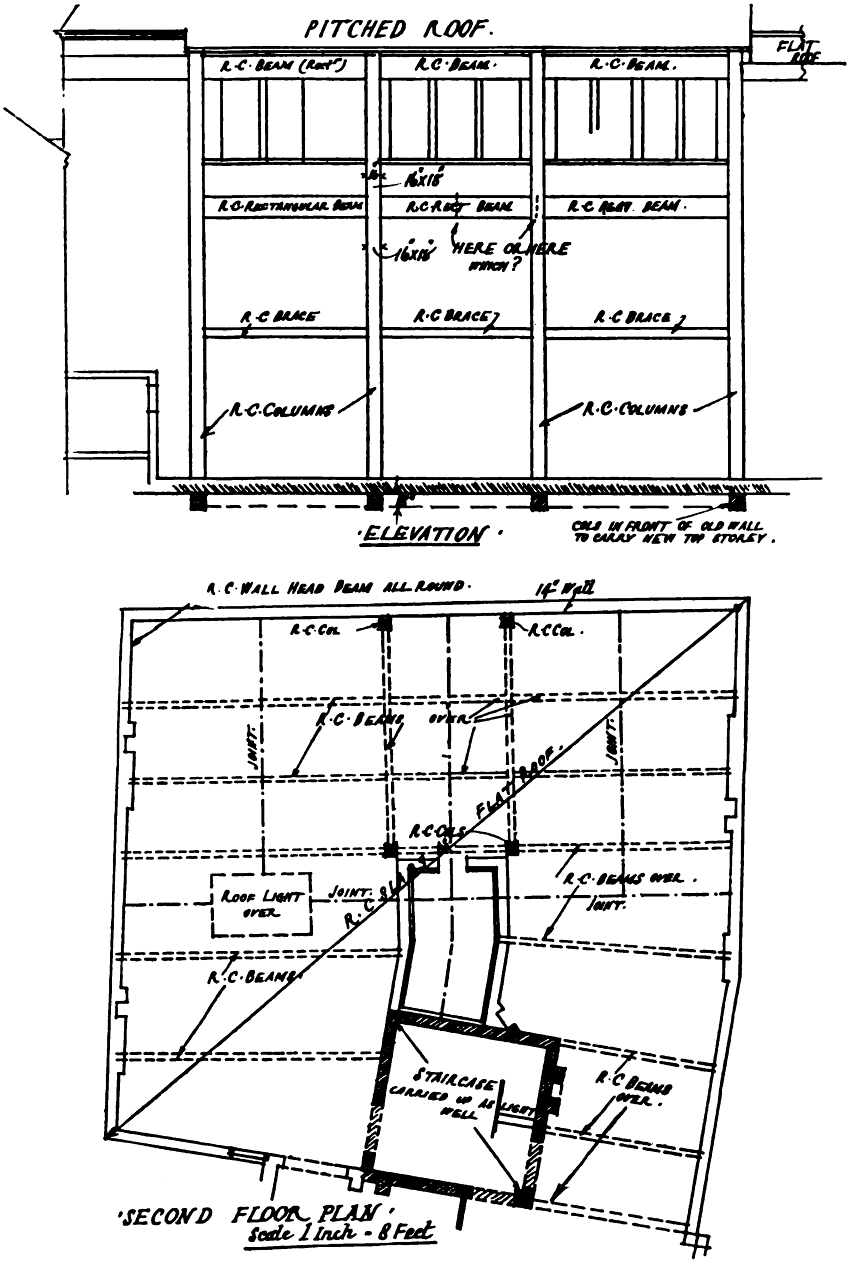
At Keene, New Hampshire, U.S.A., the widest paved street in the United States was recently repaved with concrete, which was selected for the purpose because of its wearing qualities. The street is the main street of the town, and is 140 ft. between kerbs. The concrete is 7 in. in thickness, containing steel mesh, and all transverse joints contain pre-moulded bituminous filler to provide for expansion. The mixture used was one part cement to two parts sand and three parts crushed granite. Half of the 140 ft. width was laid at a time, and is divided into three sections by plain butt joints.

At the street crossings for pedestrians a 10-ft. strip has been laid with a darker concrete made by incorporating 2 lb. of lamp black per bag of cement into the mixture; this darker concrete is laid 2 in. thick on the ordinary concrete to define the crossing places.

It is claimed that this is the widest concrete-paved street in the world.

Concrete Road at Keene, New Hampshire, U.S.A.

THE WIDEST PAVED ROAD IN AMERICA.



JOINTS IN FLOOR SLABS AND BEAMS. (*See p.* 167.)

QUESTIONS AND ANSWERS RELATING TO REINFORCED CONCRETE.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.*—Ed.**

JOINTS IN FLOOR SLABS AND BEAMS.

Question.—I enclose plan (*see p.* 166) of a second floor of a building in course of erection with the roof beams, etc., marked on. The roof is to be a reinforced concrete slab reinforced with ·1 wire mesh and covered with asphalt.

Would you give me your opinion as to whether the places I have indicated would be satisfactory jointing places for beams and slabs, as it is most unlikely the whole flat will be laid in one operation.

With regard to the elevation (which refers to another part of the same building), would it be better to joint the rectangular beams over the columns or in the centre of the spans (that is assuming a joint is found unavoidable) ? The beams have been worked to a $BM = \frac{WL}{8}$.—A. N.

Answer.—The position of joints suggested appears to be quite satisfactory. It is better to joint the rectangular beams at mid-span than over the columns. The reason for this is that at the columns the concrete is subject to heavy vertical compression in the column in addition to the stresses due to beam action. It is also very difficult at the column section to make an entirely satisfactory joint in the concrete, as there are many more rods interfering with proper hacking of the old surface. We notice the beams have been designed for a moment of $\frac{WL}{8}$, but we presume there is plenty of top steel over the support to resist reverse moment, otherwise there will be cracking between the beam and the column near the support and the resistance shear will be greatly diminished.

REINFORCED CONCRETE DESIGN.

Question.—I shall be obliged if you can give me any information with regard to the following :—

"Reinforced Concrete Design," Faber, Vol. 2, pages 161–171—shear resistance : It is not quite clear what procedure is suggested in designing a beam against shear, presuming that certain dimensions of concrete and steel have already been found sufficient to resist bending moment.

Do I take it that the following is the method adopted by Dr. Faber :—

All bars bent to be always bent up at an angle of 45 deg., and spaced either "2 a" apart in the single system, or "a" apart in the double system, and that no other spacing is to be used.

With regard to direct compression, it is noted that the area of bars to be carried through to the support must not be less than 0·675 per cent. of concrete area. Does this mean steel at top and bottom, or at bottom only ?

With doubly reinforced beams it is stated : 1·55 per cent. of *bd* steel in lower flange and 0·675 per cent. in upper, or a total of 2·22 per cent. of *bd* steel in the beam. These conditions would therefore nullify any previous calculations that had already been made for *BM* and make the design depend upon the shearing stresses entirely.

In the example given in *Concrete and Constructional Engineering*, Vol. 17, No. 4, 1922, etc., the shear resisted by inclined compressions is taken to be equal to that resisted by the bent-up bars and no example is given of the procedure to be followed in actual design as required in the book referred to above. I consider it would be of great advantage to readers if you could provide examples of a short beam with heavy load reinforced against shear in accordance with the principles laid down in Dr. Faber's book.

Further, in the examples given in *Concrete and Constructional Engineering*, the positions of the bent-up bars are shown and also their number, these being then calculated to see if their resistance is sufficient, but nothing is said as to the method first followed in obtaining the points at which the bends are to be made. Are these points obtained with regard to the *BM* diagram as shown in Hool and Whitney's "Concrete Manual"?

If a continuous beam is reinforced with 2·22 per cent. of longitudinal steel passing throughout the whole length of the beam, all questions of economical design (or 0·68 per cent. of reinforcing steel) and design to obtain proportionate stresses in steel and concrete would appear to be nullified, and the design would depend upon shear stresses entirely. Would it not therefore be quicker to design first against shear and afterwards check up for *BM*?

Could not a set of diagrams be provided to design against shear, both for bent-up bars and stirrups, single and double systems, similar to those given in the "Concrete Designers' Manual," by Hool and Whitney, but in this case with the concrete not calculated to take one-third shear, which latter Dr. Faber states is incorrect?—P. F.

ANSWER.—It is not intended in "Reinforced Concrete Design" to suggest that beams are always to be bent up at an angle of 45 deg. On the contrary, the angle of the rods should depend on the ratio of depth to span of the beam. Relatively deep beams should have the bent-up bars bent up at a large angle to the horizontal, while relatively shallow beams should have them bent up at a relatively flat angle. A good arrangement is to split the beam up into a definite number of panels, the number depending on the number of rods used in the beam, and treat each system of rods as tensile reinforcement across these panels. For example, where these rods are used in a beam and the load consists of a point load at midspan which gives consistent shear distribution, the best arrangement is to divide the beam up into four equal panels and let the reinforcement run as follows: Two rods straight along the bottom, two rods bent up diagonally across the two middle panels, and the remaining two bent up diagonally across the end two panels. A similar system can be employed with advantage for other shear distribution, as, for example, for uniform loading.

As regards the rest of the question, a great many examples of shear resistance have been given in *Concrete and Constructional Engineering*, some of which have since been reproduced in "Reinforced Concrete Simply Explained," which we think our correspondent might refer to with advantage.

In reply to the last paragraph but one, it is not as a rule best to design first against shear and afterwards check the bending moment. The best way is generally to determine the size of the beam in such a way that the total shear divided by the effective area will not exceed a figure which lies somewhere in the neighbourhood of 150 to 200 lbs. per sq. in. The area of reinforcement for bending moment is then calculated, and the rods obtained in this manner are then distributed in such a way as to give the best shear resistance consistent with it at any section giving sufficient bending resistance. If it is then found the shear resistance is insufficient this deficiency is made up by adding stirrups as may be required.—O. F.

SHEAR IN BEAMS.

QUESTION.—I should be much obliged if you would kindly give me your views on the much-discussed question of shear in reinforced concrete beams.

What are the permissible stresses which may be safely used in beams, which are correctly and carefully designed, assuming due consideration has been given to bond resistance of rods, points where tension rods may be bent up for diagonal tension, the bends being given a radius of 7 diameters of rod as recommended in Faber's "R.C. Design," Vol. II, and the top portion of the rods being carried along the compression flange to give adequate bond resistance?

In "R.C.S.E.," p. 47, 16,000 lbs. per sq. in. is taken in the rods used in diagonal tension, in accordance with L.C.C. regulations, but on page 75 it is recommended that a stress not exceeding 8,000 lbs. per sq. in. be adopted. In February, 1921, of *Concrete and Constructional Engineering*, article by Dr. Faber, 10,000 lbs. per sq. in.

is taken on both stirrups and inclined tension members. I suggest that if adequate precautions are taken as outlined above a stress of 12,000 lbs. per sq. in. would be quite safe in both diagonal tension and vertical stirrups. I should be glad to know if you agree with me on this point.

I am making no allowance for direct inclined compression which may be partly added to the shear resistance of stirrups and bent rods as outlined by Dr. Faber in his paper before the Concrete Institute.

I believe Dr. Faber has only allowed 8,000 lbs. per sq. in. to cover care when adequate hooks and horizontal bond are not given in the top of the beam, but what is wanted is a safe value for shear in beams without assuming waste of material, which are reasonably designed, and in which care is taken over these details.

I feel that this is a point on which information would be much appreciated by a large number of your readers, who, like myself, have studied Dr. Faber's " R.C.S.E." and his other works as well as his contributions to your valuable publication.—A. S.

ANSWER.—It is desirable to keep the stress in inclined rods and stirrups down to a low figure owing to the great difficulty in making the ends of these members sufficiently fixed to take a high stress without over-stressing the concrete or bending the rods. The exact stress depends on circumstances. Where it can be ensured that a radius of 7 diameters of rod is given at the bends, and if the bent-up rods are run along the top of the beam a sufficient length to fix them entirely by adhesion instead of being hooked over as soon as they reach the top of the beam, then a stress of 16,000 lbs. per sq. in. might be perfectly safe. If, on the other hand, the bent-up rods are not run along the top flange as suggested, or the bends in the rod are to a radius of much less than 7 diameters, then a proportionately lesser stress must be taken for which an exact figure cannot well be given without having the details of a particular case in view, but 8,000 to 10,000 are figures suggested as frequently meeting the average requirements. I think this gives your correspondent the information he wants, and if I say that he is quite correct in stating that my only object in reducing the stress in certain cases is to avoid over-stressing the concrete under compression at hooks and bends and exceeding the safe adhesion stress between concrete and steel, I think he will be in a position himself to determine in any particular case what would be a proper stress on the steel to adopt, but if he should require further information I should be glad to hear from him again.—O. F.

REINFORCED CONCRETE RAFTS.

QUESTION.—I shall be pleased if you will reply to the following :—

(1) When the subsoil is bad, which is the best system to adopt, viz. piling or reinforced concrete raft ?

(2) Is there any objection to using a reinforced concrete raft ?

(3) In calculating raft beams and slabs, is it safe to take $\frac{WL}{24}$ for the dead-load bending moment at the middle of the slabs and beams.—D. K. B.

ANSWER.—The answers to paragraphs (1) and (2) depend, of course, entirely on the subsoil, and no general rule can be given. It depends entirely on conditions.

In reply to (3), we think it would be quite safe to design the mid-span sections of beams and slabs of rafts for $\frac{WL}{24}$ provided of course the end sections are designed for $\frac{WL}{12}$ and that the live-load is separately treated for in accordance with the usual allowance for bending moment. This applies, of course, to the interior panels only, and those near the outside of the raft will require separate treatment.

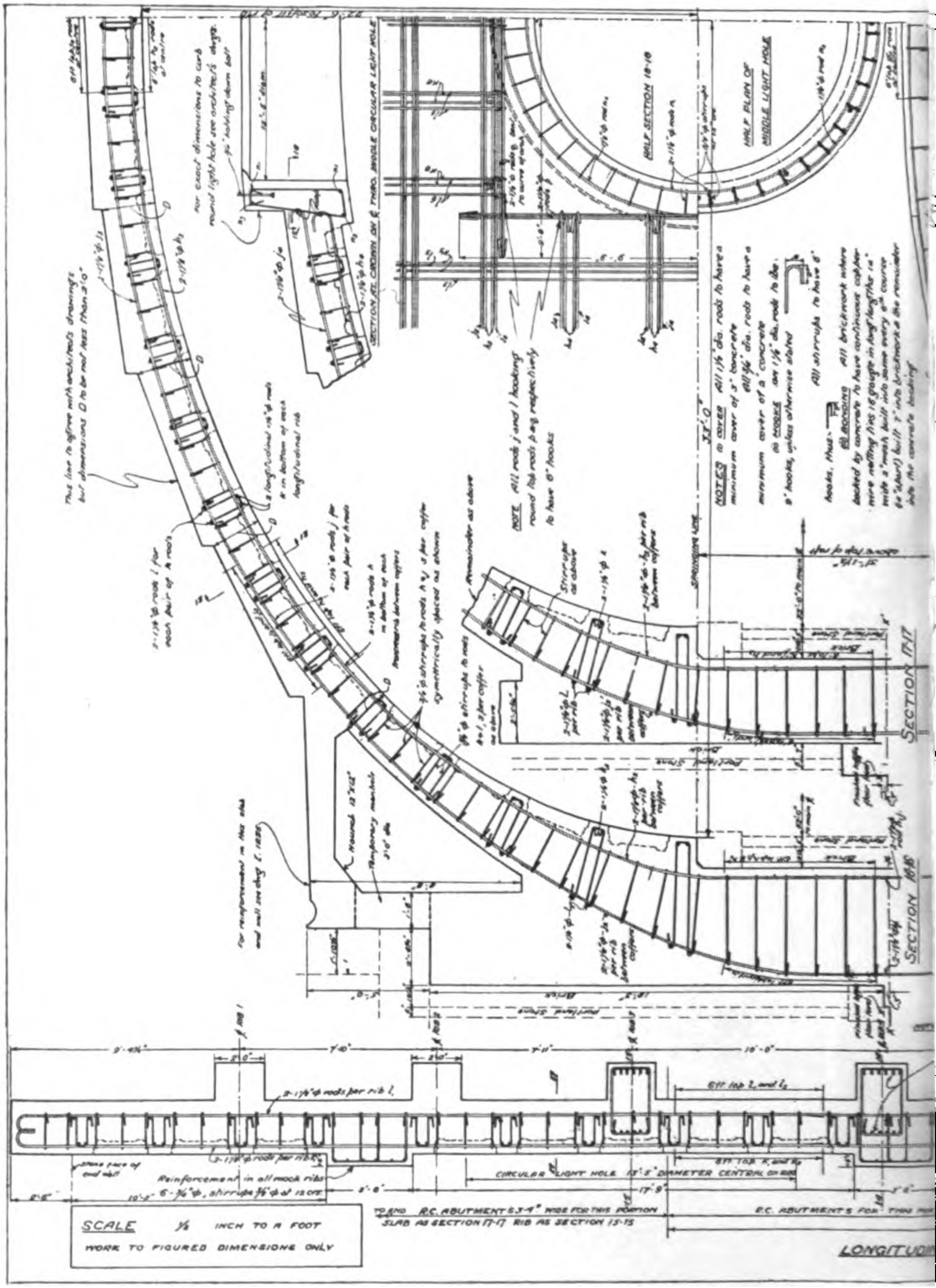
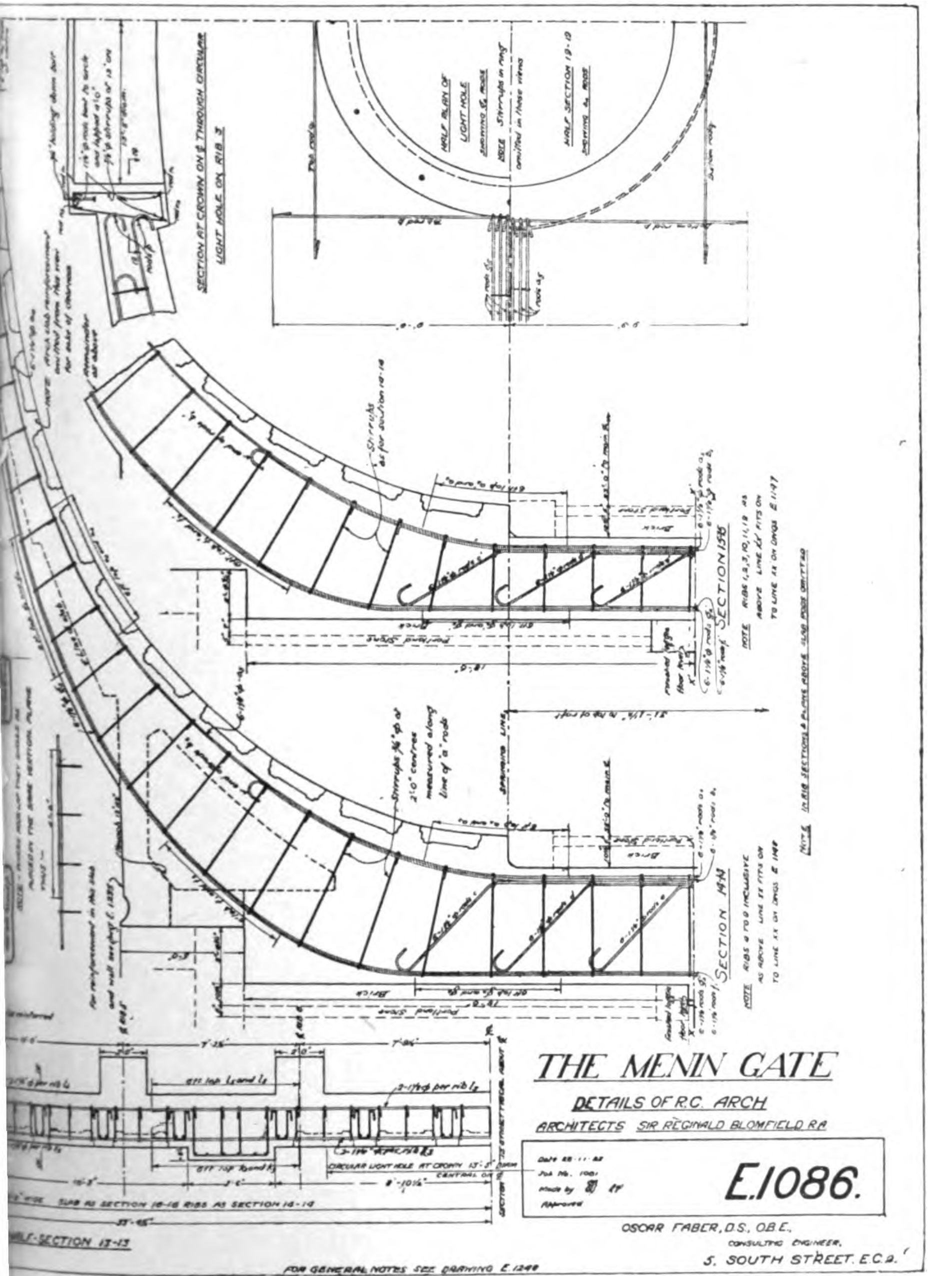

SCALE 1/8 INCH TO A FOOT
WORK TO FIGURED DIMENSIONS ONLY
9'-4½"
7'-10"
7'-11"
10'-0"
2'-0"
2'-0"
2-1⅛"φ rods per rib l.
Eff. lap l₁ and l₂
Eff. lap k₁ and k₂
3-1⅛"φ rods per rib k.
Stone face of end wall
Reinforcement in all mock ribs 6-⅜"φ, stirrups ⅜"φ at 12 crs.
2'-6"
10'-2"
3'-6"
17'-9"
CIRCULAR LIGHT HOLE 13'-5" DIAMETER CENTRAL ON RIBS
TO END R.C. ABUTMENT 6.3-4" WIDE FOR THIS PORTION
SLAB AS SECTION 17-17 RIB AS SECTION 15-15
R.C. ABUTMENTS FOR
LONGITUD
SECTION 17-17
SECTION 16-16
HALF SECTION 18-18
HALF PLAN OF MIDDLE LIGHT HOLE

Fig. 3.—FOUNDATIONS OF THE



[Sir Reginald Blomfield, R.A., Architect, Dr. Oscar Faber, O.B.E., Consulting Engineer

NIN GATE MEMORIAL. (*See p.* 151.)

INFLUENCE OF AGGREGATES ON CONCRETE.

In the course of an address at the last annual convention of the American Society for Testing Materials, Professor Duff A. Abrams dealt with the influence of aggregates on the durability of concrete.

Recent investigations and observations had shown, he said, that the quality of concrete as measured by its strength and resistance to wear was dependent to a large extent on the relative quantities of cement and water used in the mix, and to a lesser degree on the quality of the aggregate, so long as it was properly graded, clean and structurally sound.

The aggregate should be graded from the finest particles up to as large a size as the nature of the work permitted. It should be free from injurious amounts of loam, clay, organic impurities, alkalies, etc., and it should be structurally sound in order that it might resist the forces to which it was exposed due to load or to weathering action.

Tests for concrete aggregates, such as grading (sieve analysis), abrasion, organic impurities, silt, specific gravity, unit weight, and sampling, or strength tests on mortar or concrete at 7 and 28 days, did not serve in all cases to differentiate between materials which were suitable and those which were unsuitable for concrete ; for example, the behaviour of an aggregate upon exposure to weather would not be determined by any of the tests commonly employed. Some forms of rocks such as shales, feldspathic and micaceous sands, were readily broken down upon exposure to weather, and hence should be avoided as concrete aggregates. Special tests had been suggested for revealing the presence of soft particles, such as freezing and thawing, test for quantity of shale in sands and gravels, tests for mica, impact tests for gravel, modified abrasion tests, etc.

Recent investigations had shown that the strength and resistance to wear of concrete was dependent only to a slight degree upon the weight, hardness, or toughness of the material of which the coarse aggregate was composed, so long as the compressive strength of the material was not lower than that of the concretes. The high strength secured from light-weight aggregates consisting of burnt shale had shown the fallacy of the older views that the strength of the concrete was dependent upon the strength of the aggregate. More thorough investigations had shown that concrete made from limestones, gravels, granites, traps, sandstones and blast-furnace slag as coarse aggregates, gave essentially the same strength, so long as the grading was similar and the quantity of water absorbed by the aggregate was taken into account.

Experience had shown that rocks which gave comparatively high loss in the abrasion tests were entirely satisfactory for the wearing surface of concrete roads. The softer limestones and in some cases sandstones had given excellent results. At certain points along the Gulf Coast sea shells had been used as aggregates in concrete roads. The reason for steady lowering in the requirements of aggregates for concrete roads, which had been noticeable during the past few years, was partly due to the change in the nature of the traffic on our highways. Rubber-tired vehicles produced little or no surface wear on a properly constructed concrete road.

Tests of concrete exposed to fire, and observations on the condition of buildings which had been damaged by fire, had demonstrated that the fire resistance of concrete was dependent to a large degree on the mineralogical composition of the aggregate. Siliceous aggregates, particularly those composed largely of quartz, gave poor results ; limestones, trap rocks and blast-furnace slag were more suitable for concrete likely to be exposed to fire or to extremely high temperatures.

Little definite information was available on the relative merits of different types of aggregates on the resistance of concrete to alkali or sea water ; such tests as had been made indicated that the quality of the aggregates exerted comparatively little influence. Field and laboratory tests now under way were expected to throw further light on the behaviour of aggregates of different types on the resistance of concrete exposed to highly concentrated sulfate solutions.

The strength and durability of concrete depended to a large degree upon the quality of the concrete, and only to a minor degree upon the characteristics of the aggregates used. In other words, if proper methods of proportioning, mixing, placing and curing were employed, concrete of acceptable quality could be produced from aggregates which were generally considered to be inferior; on the other hand, poor concrete might result from the use of constituent materials of the highest quality, if proper methods were neglected. Care to avoid an excess of mixing water and proper provisions for curing were the most important factors in producing durable concrete.

BOOK REVIEWS.

Quantity Surveying for Builders. By Wilfred L. Eversbed, F.S.I.

London: Chapman & Hall, Ltd. 243 + xvi. pp.
Price 10s. 6d. net.

THIS volume is an addition to The Directly-Useful Technical Series, and it is therefore intended for the practical man as well as the student who is undergoing a training in theory. The author has had considerable experience in teaching the subject dealt with in this book, and thus he is able to appreciate the difficulty that many beginners have in grasping the principles and methods which are essential as a basis when starting out to deal with quantity surveying. Numerous explanations have been given throughout in order to show the reasons for dealing with the various items in the correct manner, and the reader should be able to follow each step with a full understanding of the subject.

At the commencement of the book some notes are given on Mensuration as applied to Quantity Surveying, together with some useful tables for ready reference, and the author then proceeds to deal with the various sections of quantity surveying proper in the order which is followed in practice. The most important operation is that of "taking off," and nine chapters are devoted to this part of the subject. Various methods are considered and explained, and the system advised is the one in which the work is divided into three main divisions, comprising:—(1) The carcase; (2) the joinery and finishings; and (3) the drains, sanitary work, fencing, etc.; and this is the system followed throughout the book. A chapter is given on quantities for alterations and repairs, which necessarily call for some modification of the method adopted for new buildings.

The second part deals with "working-up," which includes abstracting and billing, and it is on this part of the work that the beginner will ordinarily commence his duties until such time as he is sufficiently experienced to deal with the question of taking-off the actual quantities.

The third and fourth parts of the book deal with Schedules and Accounts respectively, and no part of the subject is omitted. Various examples and examination plates are given for the use of the reader who is desirous of working up the subject for examination purposes, and the volume can be thoroughly recommended as a well-written treatise that will give an excellent training whether required for the office or the examination room.—A. L.

Proceedings of the American Society for Testing Materials. 2 Parts.

Philadelphia: The Society. Price 6 dollars each Part.

THESE two bulky volumes contain the reports of the proceedings of the twenty-sixth annual meeting of the American Society for Testing Materials, held at Atlantic City in June last year, and as usual contain a great deal of information relating to new researches in the characteristics and application of materials.

Part I (1,006 pp.) contains the annual reports of thirty-two of the standing committees of the Society, together with the discussion thereon at the annual meeting; 103 tentative standards which have either been revised or are published for the first time; the annual address of the President and the annual Report of the Executive Committee.

Part II (683 pp.) contains fifty technical papers, with discussion. The technical papers contain valuable information on results of investigations by experts in the field of engineering materials, and the reports of the Committees cover ferrous and non-ferrous metals, cement, ceramics, concrete, gypsum, lime, preservative coatings, petroleum products, road materials, coal and coke, waterproofing materials, electrical insulating materials, shipping containers, rubber products, textile materials, methods of testing, and nomenclature and definitions.

The publication of such voluminous reports by one technical body gives an idea of the vast amount of research work now going on in the United States, and in view of the comparatively insignificant attention which is given to experimental work in the field of building and constructional materials in this country it is not surprising that we look to America for the bulk of our experimental data.

Materiaux de Construction—Pierres. By A. Mesnager.

Paris: J. B. Baillière et fils. 514 pp.; 110 illustrations. Price 45 fr.

A VERY complete treatise on stone as a building material, this book is divided in two main parts dealing with natural and with artificial stone respectively. The author bases his grouping of natural stone upon the hydrochloric test and arranges the whole material in three sections according to the behaviour under the former test. After an exhaustive account of the different kinds of stone generally met with, a full description is given of the various methods used, both in the field and in the laboratory, for determining the properties and the suitability of the stone for constructional purposes, and finally a chapter is devoted to quarrying and mining. At the end of the book no less than 17 "annexes" are appended, which take up half the reading matter and contain a large number of tables giving various properties of the materials generally used for building construction—weight, crushing and tensile strength, modulus of elasticity, co-efficient of expansion, etc., also comparative figures for resistance to wear, shock, etc. A series of tables gives numerous particulars of tests on bricks and tiles, but, in common with the tables dealing with the large variety of stone enumerated in the annexes, the utility of this information, from the English reader's point of view, is somewhat restricted as it deals mainly with local products. The last annexe, covering nearly 100 pages, is an extract of the French regulations for the execution of public works contracts, and as such is, of course, essentially of local interest.—R. N. S.

Beton-Kalender, 1924.

Berlin: Wilhelm Ernst & Son. 546 pp.; 543 illus. Price 4s. 2d.

THIS concrete pocket-book is an exceedingly handy little volume containing a wealth of useful and interesting information in connection with concrete, plain and reinforced. Some years ago the book used to appear in two parts, of which the first was devoted to the more theoretical treatment of the strength of materials in general and of reinforced concrete in particular, while the second part was given up to the mainly practical investigation and description of various structures in reinforced concrete. The two parts are now combined in one volume, an alteration which certainly makes it handier for reference, at the cost, however, of certain omissions, which may or may not be considered essential. One of the chapters that has disappeared through this arrangement is that dealing with foundations, a subject that was treated very fully, with a number of interesting data; while regretting the loss of this chapter, the more comprehensive treatment of building construction must be welcomed as a set-off against this; particularly interesting in this age of housing schemes is the chapter dealing with a number of various building blocks and the manner in which they are used, a description being also given of different methods of building hollow concrete walls *in situ*. In this connection the chapter dealing with the various manufactured concrete articles, such as blocks and tiles of all descriptions, artificial stone, etc., is also of interest. The theoretical part of the book is practically the same as before, but certain subjects are more fully treated, such as the continuous beam, the various forms of stiff frames, arches with or without hinges, etc. This part is, of course, specially useful for the designer, to whom the book offers much useful and detailed information, tables and diagrams. —R. N. S.

CONCRETE PRODUCTS.

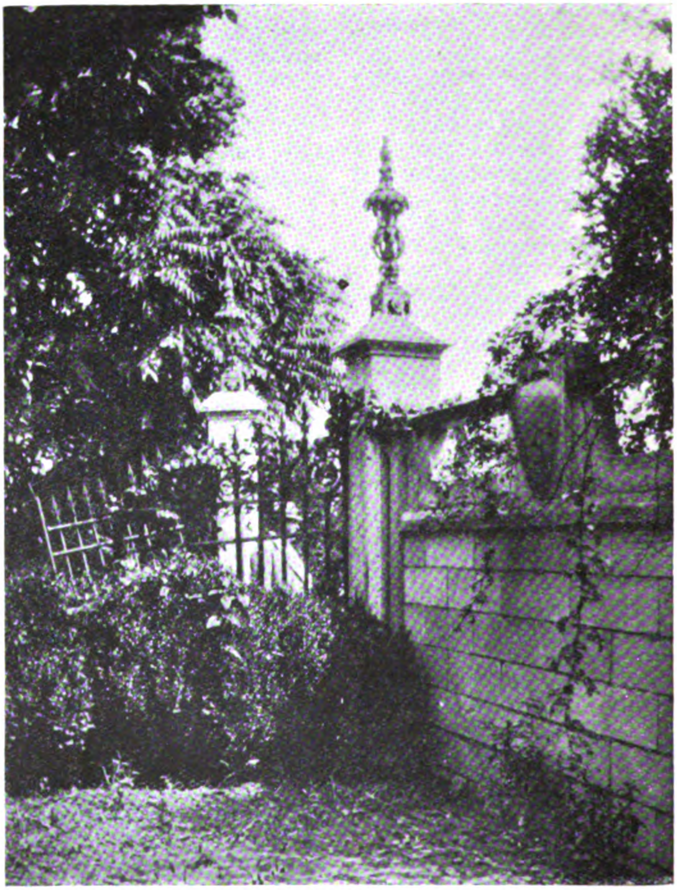
In view of the increasing demand for pre-cast concrete goods, and of the size to which the concrete products industry has now grown, we are giving a section in each issue to developments in the manufacture and uses of these articles. Descriptions and illustrations of new concrete products or new applications of concrete, for publication in this section, will be welcomed.

EFFECT OF HEAT ON CONCRETE PRODUCTS.

JUDGING from a letter received from a correspondent in New Zealand, concrete products are being used for a great many purposes in that country. The letter raises the question of the effect of heat on concrete washing-coppers, and as it is of general interest we print it below, with some observations of our own, in the form of a question and answer :—

QUESTION.—I am foreman of a company manufacturing a number of concrete articles, such as septic tanks, wash-tubs, sinks, etc. Those first mentioned are made of concrete containing blue metal (quarry chips), fine metal dust, sand, and cement. Other articles, such as double and single chimneys, and copper-casings, we make out of pumice, a fine porous material of which I presume you know the characteristics. It is about our copper casings I wish to speak. These are built of pumice concrete with wire-mesh reinforcing, 5 parts of pumice to 1 sack (120 lbs.) of New Zealand cement. These articles turn out of the circular moulds very well, but after being in use they all more or less develop cracks from the fire stresses : what I want is to learn of a method to overcome this defect—many housewives objecting to these cracks. This pumice concrete is of itself porous, and the outside of the copper casing does not get unduly hot when used, the porosity of the pumice concrete allowing, I suppose, for radiation. I have also been instructed to place three diagonal wires in the reinforcing each side of the firebox, but notwithstanding this cracks still occur. I was wondering if the wash we apply to the copper-casing outside for finish ought to be discontinued—a wash-mixture of cement and waterproof powder ? Of course I realise that these articles, subjected as they are to fierce heat on washing-days, must expand and contract, thus making for cracks in the structure, but I cannot get over the trouble. We send them out of our yards at four weeks old ; you may say this is too soon, but some we tested much older than four or six weeks cracked under fire stresses. I had thought of cutting out the wire reinforcing, but that is not practicable. We send them all over the place by rail and steamer, etc., and they are subjected to a great deal of rough handling—we do not crate or protect them in any way. Personally I feel this is a mis-

AN AMERICAN EXAMPLE OF CONCRETE STATUARY.



A CONCRETE WALL AND GATEWAY.

take in the case of those going far afield. Would a proportion of silicate of soda in my mix of this pumice concrete do any good ? It would harden it of course, but at the same time it would destroy the porosity of the mass, thus checking heat evaporation, just as, in my opinion, the wash I use does now.—J. M. P.

Answer.—Concrete made from pumice is quite familiar here, and has been much used in cases where lightness was specially important.

As regards the cracking of concrete coppers, we think it unlikely that any concrete articles of this kind, which are constantly exposed to the direct action of intense heat, can be guaranteed against cracking. The only suggestions we can make are the following :—

(*a*) Could not the coppers be lined inside with fire-brick after being set in position ?

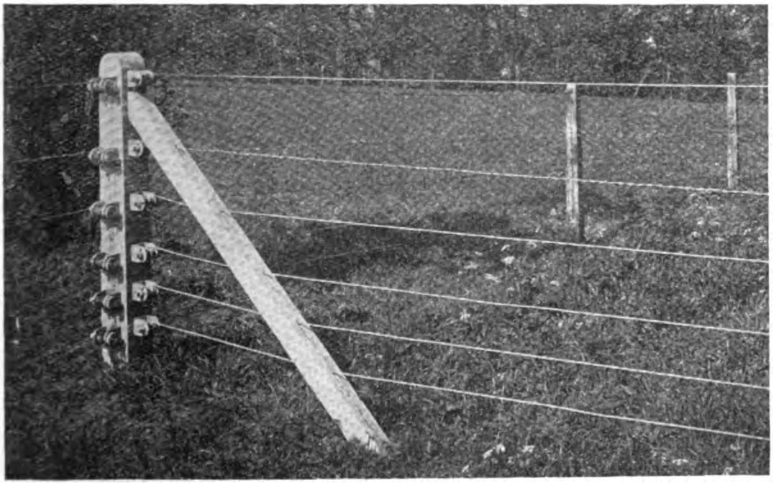
(*b*) Cracks will tend to be avoided by making the copper as thin as possible. You did not give the actual thickness or a detail drawing, so it is impossible to give you more than very rough suggestions. The effect of making it as thin as possible is to reduce the difference of temperature between the two sides of the concrete, and therefore to reduce temperature stress. If, however, the cracking is due to actual disintegration of the concrete owing to the high temperature reached, then of course nothing you can do in the design will remedy the defect and an internal lining is essential.

(*c*) If the effect of reducing the thickness is to make the concrete too weak to stand rough treatment in transit, this can of course be overcome by reinforcing it more heavily with wire mesh or expanded metal, or alternatively by crating it.

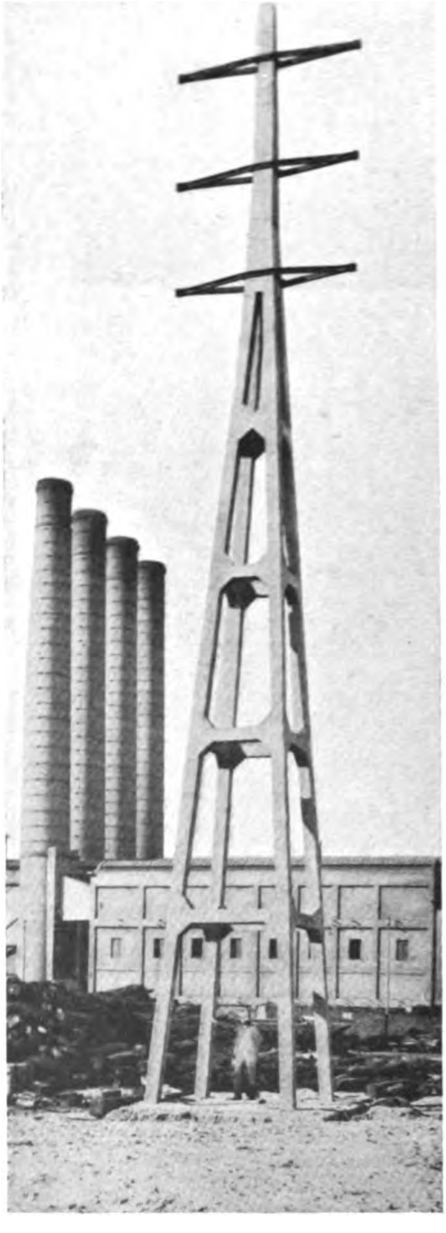
(*d*) We are afraid no wash on the outside will make very much difference one way or the other, nor will any mixture to the concrete appreciably affect this problem.

CONCRETE CORNER POSTS.

We illustrate below a concrete corner post made by the Concrete Unit Co., Ltd., of Trafford Park, Manchester. The posts, which are supplied in various sizes, are made of concrete composed of a 1 : 1 : 3 mixture of Portland cement, sand, and ⅜-in. clean hardcore. The core of the post is surrounded with a ¾-in. rendering of fine granolithic concrete consisting of a 1 : 1½ : 1½ mixture of Portland cement, sand, and granite chippings, giving a cast stone finish and protecting the reinforcement from the weather. This rendering is cast in the mould with the hardcore centre in one operation. The reinforcement consists of four round mild steel rods, from ¼ in. upwards, according to the size of the post.



Concrete Fencing Corner Post.



A SPANISH TYPE OF CONCRETE POWER TRANSMISSION POLE.

MORE CONCRETE COTTAGES.

In our last issue we reported the acceptance by local authorities of tenders for over 1,700 concrete cottages during the previous month. Since then the Bradford Corporation has accepted the following tenders :—

Messrs. Henry Boot & Sons, Ltd., at £418 per house, for the construction of 200 concrete houses.

Mr. W. S. Taylor, of Bristol, at £7,025, for the construction of 20 concrete bungalows.

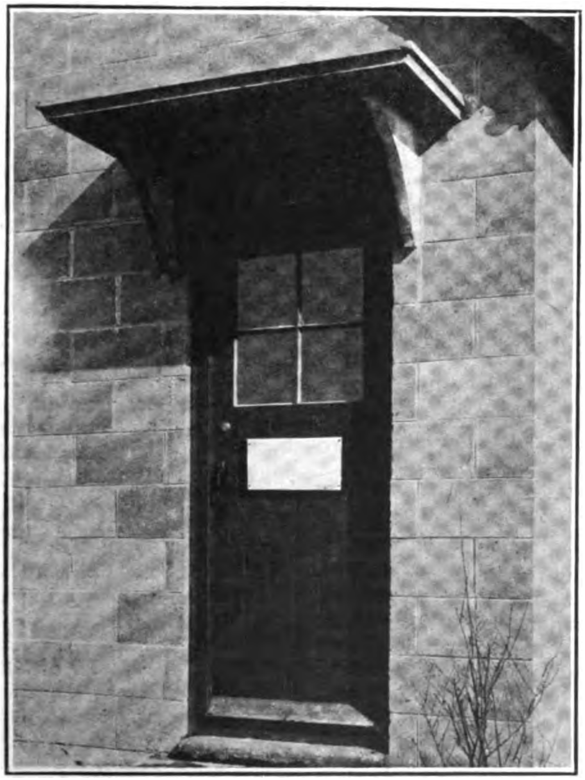
We also understand that Messrs. Ripples, of Sible Hedingham, have approached the Halstead R.D.C. for a loan in connection with the construction of 50 concrete houses for their employees.

NEW HOUSING SCHEMES.

We give below a list of housing schemes now under consideration. In the majority of cases the materials of which the houses are to be constructed have not yet been decided on, and there is time for builders who specialise in concrete construction to approach the local authorities with a view to putting forward the claims of that material; in any case, even if concrete is not used for the construction of the walling there should be openings for the supply of concrete products such as sills and lintels, paving flags, etc.

Barnsley.—The Corporation has applied for sanction to borrow £50,000 for the erection of a further 100 houses.

Bournemouth. — The Corporation



CONCRETE DOOR HOOD.

Absolutely weatherproof, and needing no painting at frequent intervals, the concrete door hood is now largely used in all kinds of house construction. The hood illustrated above was made by the Leighton Buzzard Concrete Co., of Leighton Buzzard, from Portland cement, silica sand, and granite chippings. It measures 5 ft. long by 2 ft. 6 ins. wide by 3 ins. thick.

Housing Committee proposes to construct 100 houses.

Chapel-en-le-Frith.—The R.D.C. proposes to erect 200 houses.

Eltham.—The Woolwich B.C. proposes to erect 60 houses, at an estimated cost of £30,240.

Exeter.—The City Council has applied to the M.H. for sanction to borrow £28,000 for the construction of 45 houses.

Gravesend.—The Corporation Housing Committee recommends the construction of 100 houses.

Hendon.—The U.D.C. proposes to erect 52 houses, at an estimated cost of £25,000.

Johnstone.—The T.C. has under consideration the construction of 100 houses.

Liverpool.—The Corporation intends to erect 3,500 dwellings, at an estimated average cost of £450.

Manchester.—The Housing Committee proposes to construct 484 houses in the Withington district.

Mitcham.—The U.D.C. has applied to the M.H. for sanction to borrow £16,000 for the construction of 34 houses.

Netherton.—The Dudley Corporation recommends the construction of 100 houses in the Netherton Ward.

Sheffield.—The Corporation has a scheme on hand for the construction of 250 houses a year for the next four years.

Wakefield.—The R.D.C. has applied to the M.H. for sanction to build 100 houses in the rural area.

NEW PRODUCTS' COMPANY.

Blockcrete Co., Ltd. (195,300). Registered January 25. The Factory, Broadlands Road, Hampton Park, Southampton. To acquire and carry on a business as breeze and concrete block and tile manufacturers. Nominal capital: £3,000 in 3,000 shares of £1 each. Directors: J. P. Beer, 4, Lawn Road, Southampton; A. S. Doggrell, 22, King's Road, Southampton; S. Bailey, 5, Carlton Road, Southampton; A. E. Jukes (Junior), 7, Shirley Avenue, Southampton; D. Brazier, 41, London Road, Southampton. Qualification of Directors, 100 Shares. Remuneration of Directors to be voted by Company.

CONCRETE SEWER TUBES.

The extent to which concrete sewer tubes are being used by local authorities is indicated by the following tenders which were accepted during the month of February:—

Enfield.—The U.D.C. has accepted the tender of Mr. T. W. Pedrette, of Bush Hill Park, for the construction of 148 yds. of granite-concrete sewer tube.

Falmouth.—The T.C. has accepted the tender of Messrs. G. Shellabear & Son for laying 4,340 ft. of 21-in. concrete tubes.

Luton.—The T.C. has accepted the tender of the Stanton Iron Co., at £291 15*s*. 6*d*. for the supply of 442 yds. of 18-in. reinforced concrete tubes.

Waterloo (Lancs).—The U.D.C. has accepted the tender of Messrs. J. W. Thornley & Sons, of Kearsley, for laying 567 ft. of 21-in., 525 ft. of 18-in., and 138 ft. of 12-in. diameter Stanton-Hume reinforced concrete pipes in connection with the sewerage works along the foreshore.

CAST-STONE PAVING.

There is also a considerable activity in cast-stone street paving, as is indicated from the following particulars of a few of the large number of such work recently put in hand or to be proceeded with shortly:—

London (St. Pancras).—The B.C. has accepted the tender of the Patent Victoria Stone Co., Ltd., for the supply of 2-in. artificial paving slabs, at 6*s*. 3*d*. per sq. yd.

Manchester.—The Corporation has accepted the tender of Mr. S. H. Bonsall, of Cheadle Heath, for the supply of concrete flags, and of Mr. J. A. McCullough, for paving in concrete the passage behind Leegrange Road.

Willesden.—The Government has sanctioned a loan towards the cost of a scheme for the substitution of cast-stone paving for tar-paving in various thoroughfares at Willesden.

STRESSES IN T-BEAMS WITH COMPRESSION STEEL.

WE have received the following from Professor J. Rieger, Professor at the Polytechnic High School, Brno, Czechoslovakia:—

In *Concrete and Constructional Engineering* for December, 1923, there was published a question and answer on "Stresses in T-Beams with Compression Steel," in which the writer of the question stated that the solution already given of a certain problem could not be correct and proposed another method of calculation. The expert replied that he was unable to follow the writer's figures, and thought that his original calculation given in January, 1923, was the simpler.

As an impartial observer and reader of this magazine, I take the liberty to examine the problem with the help of a new method—a logarithmic slide rule of my system for calculating reinforced concrete structures.

The principle of the rule is as follows:

In every case $f = m/\frac{J}{u}$

where m = bending moment

$\frac{J}{u}$ = modulus of resistance of the section.

The solution of this equation would be simple if we had complete design tables such as are available for steel sections.

Consider the T-beam section shown in *Fig.* 1. The dimensions $b, h, d, b', g,$ and the areas w and w_e are all variables, and the tables would be very extensive and their use impracticable. The best solution would be a logarithmic slide rule where the same results were in the form of scales. This would only be possible if the number of variables were reduced to permit of the construction of a rule of modest dimensions. This method consists in using the following new variables and parameters, β, δ, p_o,

$$\mu = \frac{m}{bh^2}$$

$$p = \frac{w}{bh} \text{ —percentage ratio tensile steel}$$

$$\beta = \frac{b^1}{b}$$

$$\delta = \frac{d}{h}$$

$$p_0 = \frac{w_e}{bh} \text{ —percentage ratio compressive steel.}$$

We take the following value of these:

$\beta = \frac{1}{3} \quad \frac{1}{4} \quad \frac{1}{5} \quad \frac{1}{6} \quad \frac{1}{8}$

$\delta = 0{\cdot}1 \quad 0{\cdot}15 \quad 0{\cdot}20 \quad 0{\cdot}25 \quad 0{\cdot}30$

$p_0 = 0{\cdot}0 \quad 0{\cdot}2 \quad 0{\cdot}4 \quad 0{\cdot}6 \quad 0{\cdot}8 \quad 1{\cdot}0 \quad 1{\cdot}5 \quad 2{\cdot}0.$

The actual figures for any given T-beam can then be applied by interpolation.

The stresses in the concrete and in the steel, c and f respectively, are found as follows: Place the cursor with hair-line over the value μ found on the logarithmic scale A on the body of the rule, move the slide to right or left until the value of p on the scale corresponding to parameters $\beta\delta$ and p_0 is also under the hair-line. Above the mark b we shall find "c" (*Fig.* 2*a*), if we have used the scale for concrete, and f (*Fig.* 2*b*), if the scale for steel has been used. In *Figs.* 2 the values taken are

$$\mu = 88$$
$$\beta = \tfrac{1}{5}$$
$$\delta = 0{\cdot}2$$
$$p_0 = 0{\cdot}6.$$

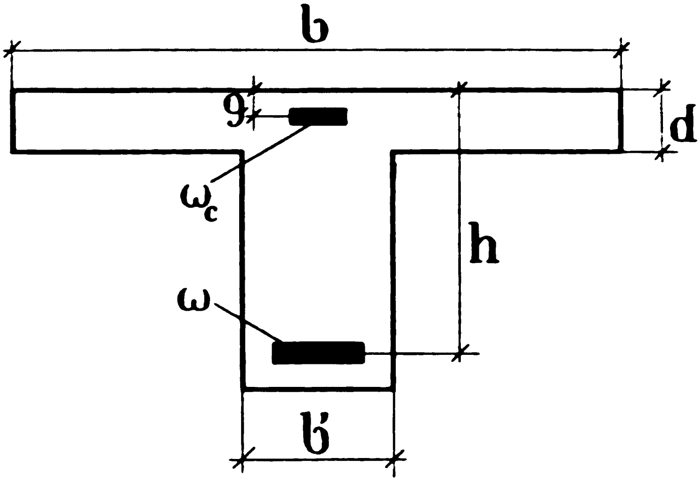


Fig. 1.

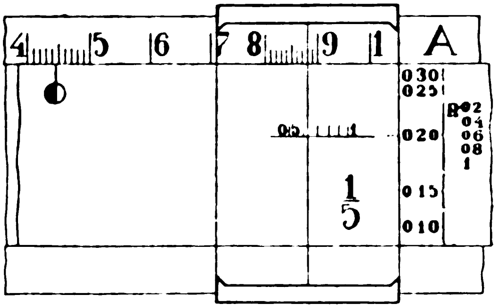


Fig. 2A.

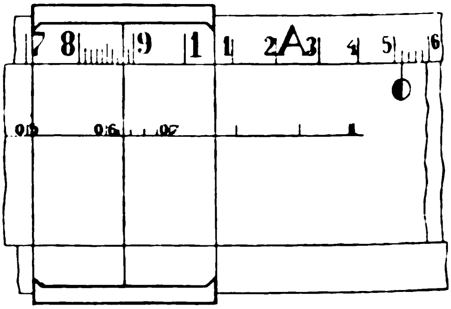


Fig. 2B.

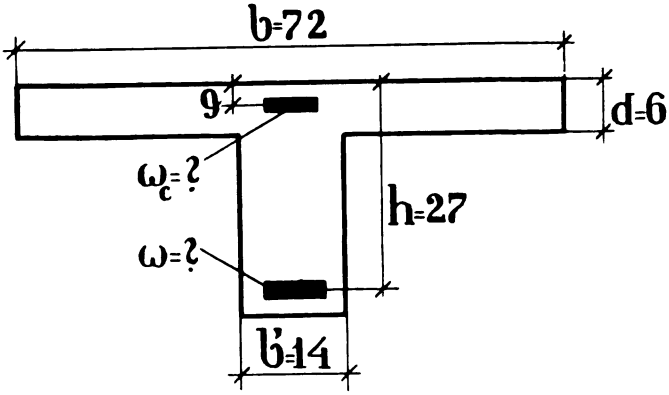


Fig. 3.

The stresses c and f were found by division. To find the dimensions, being given the stresses, we use the scale in the reverse order—multiplication.

EXAMPLE.—To find the steel areas:

Given

$$\begin{aligned} f &= 16{,}000 \text{ lbs./in.}^2 \\ c &= 600 \text{ lbs./in.}^2 \\ M &= 4{,}600{,}000 \text{ in. lbs.} \\ b &= 72 \text{ in.} \\ d &= 6 \text{ in.} \\ b' &= 14 \text{ in.} \\ h &= 27 \text{ in.} \end{aligned}$$

(See *Fig.* 3.)

$$\mu = \frac{m}{bh^2} = \frac{4{,}600{,}000}{72 \times 27^2} = 88$$

$$\beta = \frac{b'}{b} = \frac{14}{72} = \frac{1}{5}$$

$$\delta = \frac{d}{h} = \frac{6}{27} = 0{\cdot}222$$

$$x = \frac{f}{c} = \frac{16{,}000}{600} = 26{\cdot}7$$

The parameter $\delta = 0{\cdot}222$ is not on the rule, and we are obliged to use the rule twice for $\delta = 0{\cdot}2$ and $0{\cdot}25$.

For every value of β, δ and x there is a corresponding value of μ_e, found as follows: Place the mark ⫱ at $c = 600$ on scale A and move the cursor until the hair-line is over $x = 26{\cdot}7$ of the scale $\beta = \frac{1}{5}$, $\delta = 0{\cdot}2$ β/concrete/and we read on scale A:—

$$\mu_e = 82 \text{ (see } \textit{Fig. } 4a\text{).}$$

In the same manner for $\beta = \frac{1}{5}$ and $\delta = 0{\cdot}25$:—

$$\mu_e = 89 \ (\textit{Fig. } 4b),$$

and by interpolation when $\delta = 0{\cdot}222$ $\mu_e = 85$. We see that $\mu_e > \mu$ since $88 > 85$, which means that the section must be reinforced with compression steel to make up the difference between 88 and 85.

The determination of the ratio of steel required can also be found with the help of the rule. The second sliding part contains scales with compression ratio p_0. As before with $\beta = \frac{1}{5}$ and $p_0 = 1$ per cent. we find $\mu_e = 154$ when $\delta = 0{\cdot}25$ and $\mu_e = 160{\cdot}5$ when $\delta = 0{\cdot}2$ (see *Figs.* 5*a* and 5*b*).

By interpolation $\mu = 155{\cdot}5$ with $\delta = 0{\cdot}222$.

We have now found with $\beta = \frac{1}{5}$ and $\delta = 0{\cdot}222$

$$\begin{aligned} \mu_2 &= 85 \quad \text{when } p_0 = 0{\cdot}0 \\ \mu_e &= 155{\cdot}5 \text{ when } p_0 = 1{\cdot}0 \text{ per cent.} \end{aligned}$$

Hence by interpolation when $\mu = 88$, $p_0 = 0{\cdot}043$ per cent., which is the correct ratio of compressive steel required.

It only remains to determine the ratio of tensile steel p. Values of p are found above the values of x on the scale described above. We find:

$\beta = \frac{1}{5}$ $\quad \delta = 0{\cdot}20 \quad p_0 = 0{\cdot}0 \quad p = 0{\cdot}57\%$ (*Fig.* 4*a*)
$\quad \delta = 0{\cdot}25 \quad p_0 = 0{\cdot}0 \quad p = 0{\cdot}62\%$ (*Fig.* 4*b*)

and by interpolation:

$\quad \delta = 0{\cdot}222 \quad p_0 = 0{\cdot}0 \quad p = 0{\cdot}592\%$
Also $\beta = \frac{1}{5}$ $\quad \delta = 0{\cdot}20 \quad p = 1{\cdot}0\% \quad p = 1{\cdot}05\%$ (*Fig.* 5*a*)
$\quad \delta = 0{\cdot}25 \quad p_0 = 1{\cdot}0\% \quad p = 1{\cdot}1\%$ (*Fig.* 5*b*)

and by interpolation:

$\quad \delta = 0{\cdot}222 \quad p_0 = 1{\cdot}0\% \quad p = 1{\cdot}07\%$

Again by interpolation we get:

$\mu_t = 85 \qquad p_0 = 0{\cdot}0\% \qquad p = 0{\cdot}592\%$
$\mu = 88 \qquad p_0 = 0{\cdot}043\% \qquad p = 0{\cdot}61\%$ by interpolation
$\mu_c = 155{\cdot}5 \qquad p_0 = 1{\cdot}0\% \qquad p = 1{\cdot}07\%.$

Area of tensile steel $= w = 0{\cdot}61\% \times 72 \times 27 = 11{\cdot}9$ in.^{2}
8 Bars $d = 1\frac{3}{8}$ in. give $11{\cdot}879$ in.^{2}

Area of compression steel $= w_c = 0{\cdot}043\% \times 72 \times 27 = 0{\cdot}82$ in.^{2}
5 Bars $d = \frac{1}{2}$ in. give $0{\cdot}982$ in.^{2}

These results differ little from those given by the reply of the question. The method given therein is an approximate one, and there will therefore be a difference between the true stresses and those given. The equations given are correct but troublesome.

I will now show how easy it is to prove that the values $w = w_c = 12{\cdot}2$ in.^{2} do not give a precise solution with the stresses 16,000 and 600, see page 806, *Concrete and Constructional Engineering*, December 1923. We find as above:

$\mu = 88$
$\beta = \frac{1}{5}$
$\delta = 0{\cdot}222$

$$p_0 = p = \frac{12{\cdot}2}{72 \times 27} = 0{\cdot}628 \text{ per cent.}$$

The exact values $\delta = 0{\cdot}222$ and $p_0 = 0{\cdot}628$ are not found on the rule, and as before we are obliged to make several interpolations which we do not give in full.

With $\beta = \frac{1}{5}$, $\delta = 0{\cdot}2$, $p_0 = 0{\cdot}6$, $\mu_t = 88$, we read above the initial mark $c = 445$,

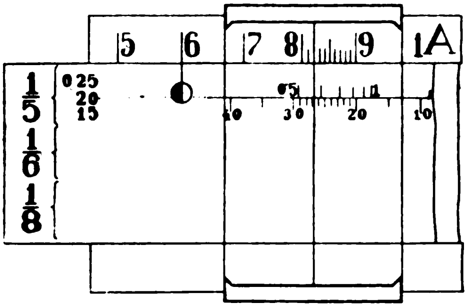


FIG. 4A.

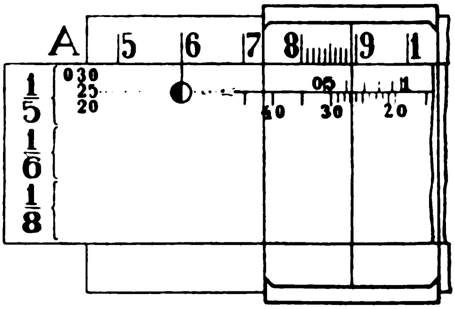


FIG. 4B.

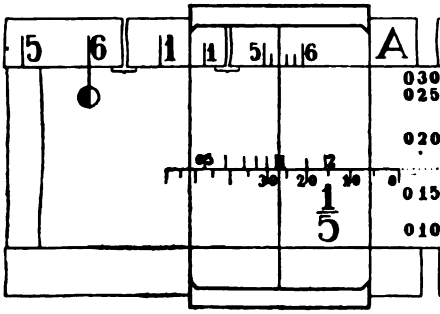


FIG. 5A.

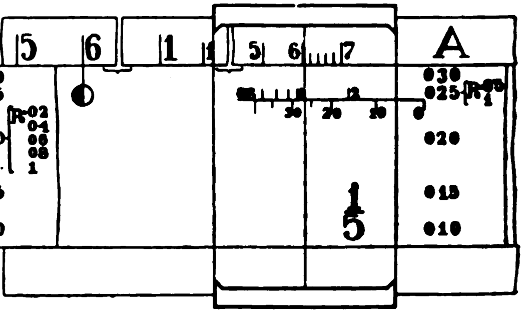


FIG. 5B.

$f = 15{,}200$ (*Fig.* 2*a*), and by interpolation after finding values corresponding to $\delta = 0{\cdot}25$ and $p_0 = 0{\cdot}8$:

$$\beta = \tfrac{1}{5} \quad \delta = 0{\cdot}222 \quad p_0 = 0{\cdot}628 \quad p = 0{\cdot}628 \quad c = 444 \quad f = 15{,}246.$$

Now apply a correction for "*g*" (see detailed instructions for using the rule) and the corrected values become

$$c = 473 \text{ lbs./in.}^2$$
$$f = 15{,}566 \text{ lbs./in.}^2$$

The difference of the value of *c* is considerable and shows the writer of the question to be correct.

⁂ We print the above *in extenso* because we wish our readers to feel that we have no desire to shield ourselves from criticism, and also because it refers to a slide-rule for reinforced concrete which our readers may find interesting. But we do not agree that our contributor was wrong. If readers will refer to the original question in our January, 1923, issue, they will see that it reads "How can the moment of resistance of a T-beam having compression reinforcement be calculated? As an example, I should like to have the following case worked out, the limits of stress being 600 and 16,000 lbs./in.^{2}." Then followed the example.

We gave the resistance moment in a few lines by a very simple method, and showed that the concrete was considerably understressed, and therefore did not trouble to calculate this stress. Professor Rieger now shows by a much more elaborate and lengthy calculation and a special slide-rule that the tensile stress can be more correctly given as 15,566 instead of 16,000 and the concrete as 473 lbs./in.^{2}.

We can only observe that the difference between 15,566 and 16,000 is so small as to have no practical significance whatever when the variations in materials and the discrepancies in the assumptions underlying the theory of design are taken into account, and certainly few practical designers would be willing to substitute a long tedious calculation for a simple one to achieve it.

Further, no single-scale slide-rule can give a figure accurate to five significant figures.

As to the concrete stress, Professor Rieger has quite misunderstood our contributor if he understood him to imply that the concrete stress was 600 lbs./in.^{2} for he distinctly states (January, 1923): "This shows the compression flange is stronger than the tension flange, which therefore limits the strength. The compression steel is much more than is required. In fact, the concrete would not be much overstressed if it were omitted."—EDITOR.]

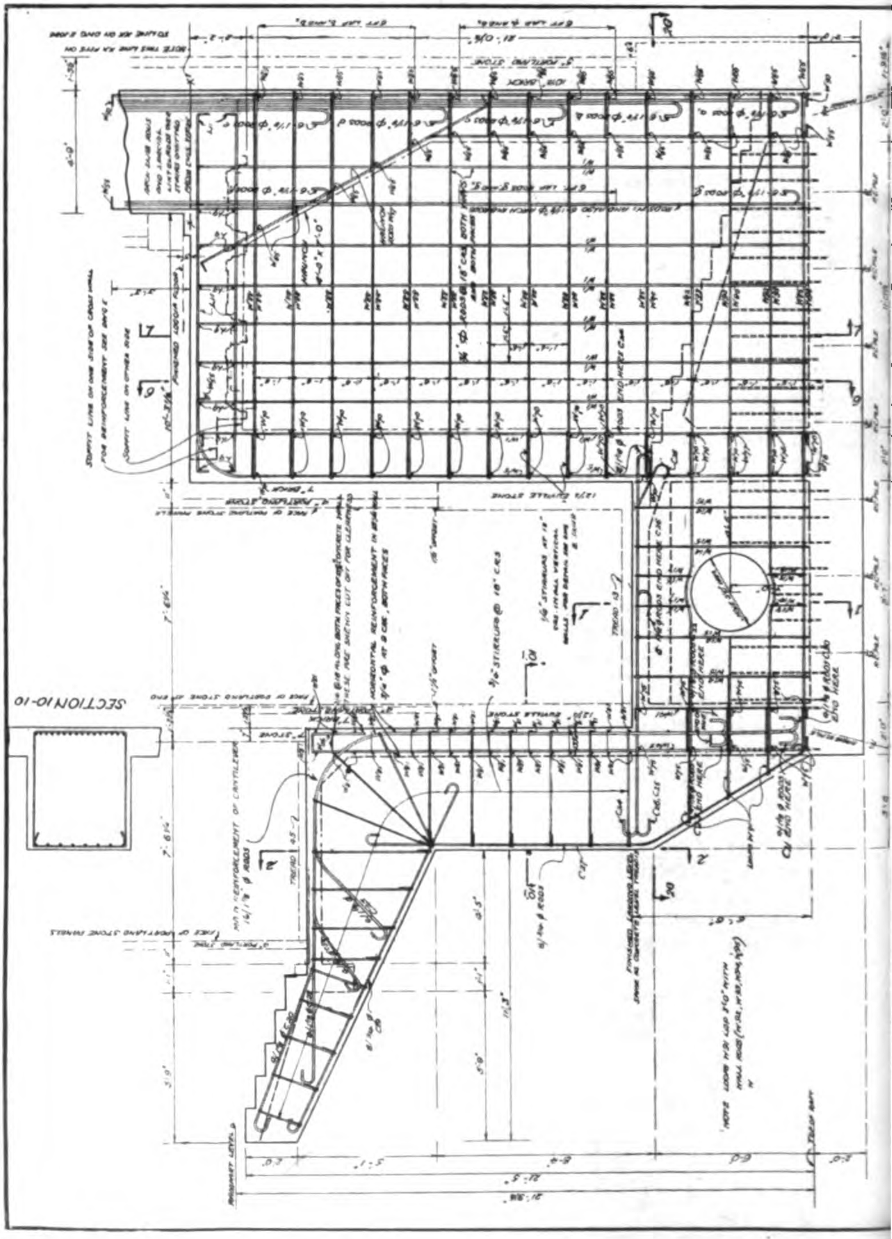
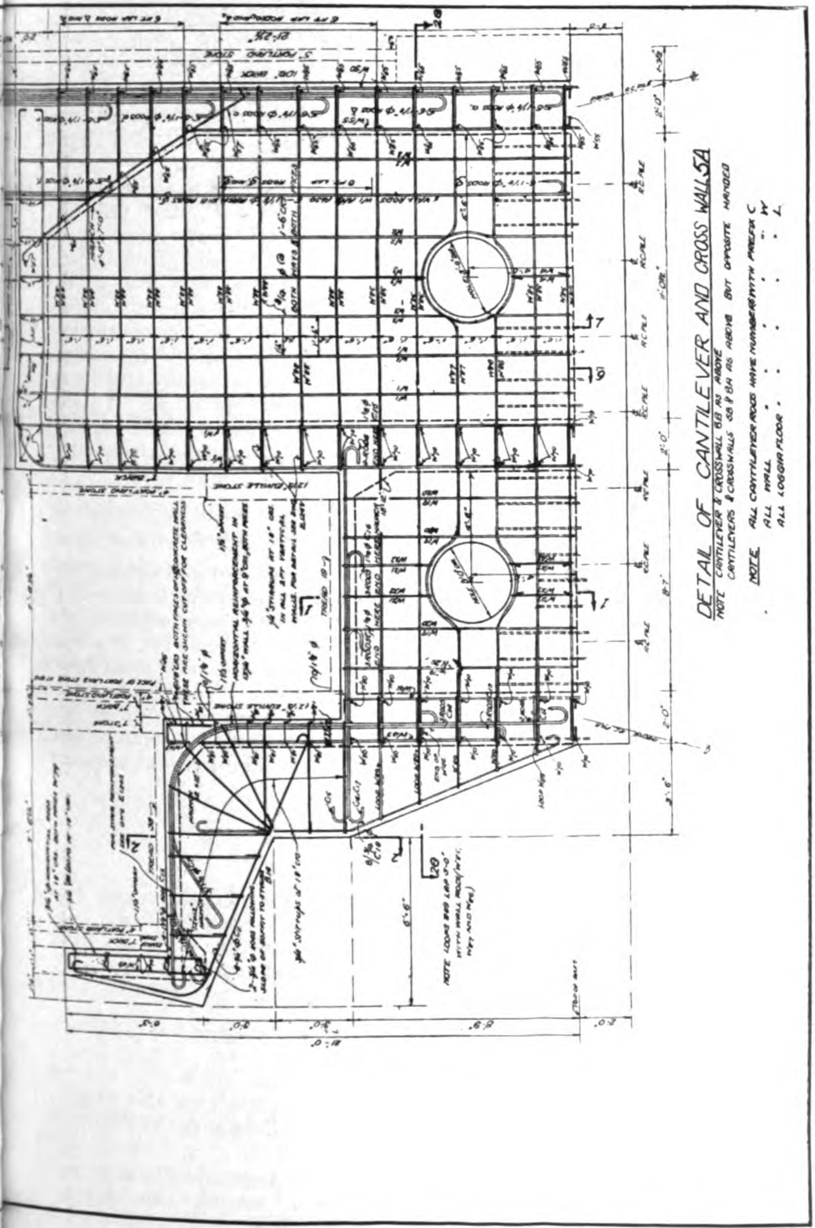


Fig. 4.—FOUNDATIONS OF T


DETAIL OF CANTILEVER AND CROSS WALL 5A
NOTE CANTILEVER & CROSSWALL 6B AS ABOVE
CANTILEVERS & CROSSWALLS 5B & 8A AS ABOVE BUT OPPOSITE HANDED
NOTE ALL CANTILEVER RODS HAVE NUMBERS WITH PREFIX C
ALL WALL " " " " " W
ALL LOGGIA FLOOR " " " " " L
NOTE LOOPS 6B9 LAP 3'-0" WITH WALL RODS
5' PORTLAND STONE
10½" BRICK
12½" PORTLAND STONE
2'-0"
8'-7"
5'-6"

[Sir Reginald Blomfield, R.A., Architect, Dr. Oscar Faber, O.B.E. Consulting Engineer.

MEMORIAL. (See p. 151.)

COLUMN FALLACIES.

A PAPER entitled "Column Fallacies" was read by Dr. E. H. Salmon, D.Sc., at the last meeting of the Institution of Structural Engineers. Eighteen points were dealt with, from which we take the following :—

That Euler's limiting load merely implies passage from one type of stable equilibrium to another, and does not involve the failure of the column.

Suppose that a perfectly straight, perfectly homogeneous long column be loaded with a longitudinal load directed along a line which coincides exactly with the centre line of the column. Further, suppose that the magnitude of the load be less than Euler's limiting value. If now the column be deflected from the straight by an external agency, it will at once restraighten itself if that agency be removed. In short, it is stable. If now the load be increased in magnitude up to, but not exceeding, Euler's limiting value for the column, the column will still remain straight, but if slightly deflected will remain bent and not re-straighten itself. It is still in equilibrium, but of a somewhat different kind. It is, therefore, quite correct to state that the column passes from one type of stable equilibrium to another; but, if the load exceed Euler's limit by the most trifling amount, the column fails immediately and completely. Engineers are, therefore, absolutely right in regarding Euler's limiting load as the failure load of the column.

As far back as 1844 Lamarle showed that if a long ideal column bend, the material would at once pass the elastic limit. I believe that his result is quite correct, and it has been confirmed by several others since. One cannot quote experimental evidence regarding ideal columns, since such columns only exist in text-books; but in several experimental studies the conditions have approached very closely to the ideal, notably Considère's (1889), also Karman's (1908) and Lilley's (1908), and in each case the long specimens failed completely when the load reached Euler's limit.

The ordinary testing machine specimen, fixed in position but not in direction (position-fixed) at each end, is both initially curved and eccentrically loaded. The central deflection y_0 of a position-fixed specimen with an initial curvature e_1 is

$$y_0 = \frac{e_1}{1 - \frac{W}{P}}$$

Hence, when $W = P$, the deflection becomes indefinitely large whatever be the value of e_1. This led to Bauschinger's definition of Euler's limit load as the value of the load under which the already existing deflection becomes indefinitely great, and the resistance of the column is overcome. This is equally true for an eccentrically loaded specimen. It is submitted that an engineer has a right to call a load which produces an indefinitely great deflection, a failure load.

That the defect in Euler's formula is the neglect of the direct compressive stress.

This is a hoary old fallacy which is still repeated in text-books to-day. It is quite true that Euler neglected the direct compressive stress, but it is also true that this makes no substantial difference to his result. Von Heim (1838) took the direct compressive stress into account, and reached as the limiting load for a column position-fixed at each end

$$W \overset{=}{>} \frac{EI}{\frac{L^2}{\pi^2} - \frac{I}{a}} = P'$$

which differs very slightly indeed from Euler's formula. Kriemler (1902) took both direct compressive stress and shear into account, and reached

$$W \overset{=}{>} \frac{\pi^2 EI}{L^2} \cdot \frac{1}{1 + \frac{W}{a}\left(\frac{S}{G} - \frac{1}{E}\right)} = P''$$

where $S = \frac{a}{Q^2} \int f_s^2 \cdot da$ is the well-known coefficient depending on the distribution of shear stress over the cross section. This, like P', differs very slightly indeed from P, Euler's value; in fact, for a rectangular cross section $P' > P > P''$, and Euler is more nearly correct than von Heim.

The real defect in Euler's formula is that it applies to an ideal and not to a real specimen, i.e., that it neglects initial curvature, eccentricity of loading, want of homogeneity, etc. Although it will represent the failure load of a long column in which the conditions are very good, it loses its validity when the load per square inch is equal to the elastic limit stress, i.e., at about $\frac{L}{k} = 110$ in a column position-fixed at each end, or 220 in a column position- and direction-fixed at each end. The L.C.C. limits for these two classes are $\frac{L}{k} = 140$, and $\frac{L}{k} = 210$. In short, Euler's formula has no validity for the ordinary practical column at all.

That the deflection of an ideal column is an indefinite function of the load.

It is usually stated that the ideal column remains straight until the load reaches Euler's limit, at which point it deflects, the magnitude of the deflection being independent of the load.

This is disproved by Lamarle, who gave as the value for y_0

$$y_0 = 4\left(1 - \frac{W}{Ea}\right)\sqrt{\frac{EI}{W}} \left\{\frac{L}{\pi\sqrt{1 - \frac{W}{Ea}}}\sqrt{\frac{W}{EI}} - 1\right\}^{\frac{1}{2}}$$

The error in the ordinary analysis arises from taking the length of the arc as equal to that of the chord.

That the Eulerian length relations have any applicability in practice.

Although the position laid down in (2) is now generally admitted, it is quite common to assume that the Eulerian relations between the lengths of columns for a given crippling load hold in practice. That is to say, it is assumed that a column position- and direction-fixed at the lower end, and quite free at the other, is equally as strong as a column position-fixed at both ends, but of twice the length; or as strong as a column position- and direction-fixed at both ends of four times the length.

Experiment has shown that in specimens for which $\frac{L}{k} < 100$ the strength is practically the same for all types of end condition, except that the effect of eccentricity of loading somewhat reduces the strength of those specimens with round ends.

The Eulerian length relations, in fact, only apply to the long ideal column, and should be deleted from the engineer's stock of ideas regarding the practical column.

That it is possible to prove the Rankine-Gordon formula theoretically.

Students are not infrequently asked in examination papers to prove the Rankine-Gordon formula. This is not possible, and the formula should be regarded merely as an empirical expression representing experimental failure loads.

If, in a column, the centre of area of any cross section lie at a distance y from the line of action of the load W, a bending moment Wy will exist, producing in the extreme fibres on the concave side a bending stress $f_b = \frac{W\,y\,v_2}{I}$, where v_2 is the distance of the extreme fibres from the neutral axis. To this must be added the direct compressive stress $f_a = \frac{W}{a}$.

Then the total compressive stress will be

$$f_c = f_a + f_b = \frac{W}{a} + \frac{W\,y\,v_2}{I} = \frac{W}{a}\left(1 + \frac{y\,v_2}{k_2}\right)$$

If y_0 be the maximum deflection of the column from the load line, this expression will give the maximum stress in the material, and hence

$$W = \frac{f_c a}{1 + \frac{y_0\,v_2}{k^2}}$$

This equation is the basis of the Rankine-Gordon formula. It is true for any end conditions. In it, everything is known except y_0 the maximum deflection. Now y_0 is a function of W, of the initial curvature, eccentricity of loading, end conditions, etc., but the initial curvature, eccentricity of loading, etc., are in general unknown. Therefore, the value of y_0 cannot be expressed in terms of known quantities, and the "proof" comes to rest at this point.

An extraordinary amount of ingenuity has been displayed in trying to get round this fundamental difficulty. Rankine, by analogy with the bending of beams, assumed that $y_0 = \frac{c\,L^2}{v_2}$, writing the formula $W = \frac{c\,a}{1 + c\left(\frac{L}{k}\right)}$. But y_0 is evidently a function of W, and therefore c_2 is a function of W and not a constant at all. If c_2 be calculated from any series of experiments, it will be found to be a very variable quantity indeed, even at the moment of failure, at which point some have supposed it to be constant; and there is no rational basis for the assumption, implied in the "proof," that $\frac{y_0\,v_2}{L^2}$ is constant.

That a "straight line formula" is the simplest column formula.

It is, of course, the simplest to plot, and possibly the simplest from which to find the load per square inch for a given slenderness ratio. Unfortunately, in column design, before one can find $\frac{L}{}$ one must find the dimensions of the cross section, and the process becomes one of trial and error. In 1876 Asimont suggested a device by which this difficulty could be avoided. If it be assumed that $a = r\,k^2$, where r is the constant depending on the shape of the cross section and a the area, it is easy to obtain from the formula an equation giving the value of a directly—a great saving of time. Now the equations thus obtained from the Rankine-Gordon and straight line formulæ are awkward to solve, but if the Johnson parabola be used the expression is very simple. Thus for mild steel, $a = a_0 + \frac{r\,L^2}{30{,}000}$, where a_0 is the necessary area of a short specimen similarly situated. Since, as Ostenfeld has shown, the Johnson Parabola represents the results of experiments rather better than any other, its merits as an empirical formula are worth consideration, even from the point of view of simplicity.

The values of *r* for different cross sections are easy to calculate. For geometrically similar cross sections the method is perfect. It is only right, however, to point out that small differences in thickness, for example, in practical cross sections, cause considerable variations in *r*, and it is wise in practical work to check the value assumed, from the resulting section.

That eccentricity of loading is the principal source of weakness in columns.

There is a tendency in some quarters to regard eccentricity of loading as the prime, if not the only, source of weakness in columns, and the majority of semi-rational formulæ for columns contain terms allowing for either or both unintentional and intentional eccentricity.

It is quite true that in a column with position-fixed ends, such as a round-ended specimen in a testing machine, eccentricity of loading has a great weakening effect, but if the ends be fixed in direction also, the eccentricity has no effect whatever. In practice one or both ends of almost every column are attached to some other part of the structure, which attachment more or less fixes it in direction, often very imperfectly, but only in very rare instances is the member free to deflect as an eccentrically loaded specimen. Yet the secant formula in various disguises is quite commonly applied to such members. The attachments referred to usually result in external bending moments being applied to the ends of the columns, often exceedingly difficult to determine with accuracy, and too often neglected in design, but the effect of such moments is not the same as an eccentricity of loading, nor is the ordinary eccentricity formula applicable.

On the other hand, initial curvature is inevitable in all columns, and alike weakens both position-fixed and direction-fixed columns. Its effects are by no means identical with those produced by eccentricity of loading. It greatly modifies the distribution of stress in the ordinary direction-fixed column as compared with the ideal, perfectly straight, direction-fixed column, and it further has the effect of considerably increasing the shearing force as compared with eccentricity of loading. There is some justfication, therefore, for the view that initial curvature is the prime cause of weakness in columns. Nevertheless, Howard, of Watertown Arsenal, who, with the possible exception of Tetmajer, must have conducted more experiments on columns than anybody else, regards reduction in the quality of the material due to effect of past history, particularly cold-straightening and stresses set up during manufacture, local permanent sets, etc. (to which might be added annealing—in fact, any cause which lowers the elastic limit), as the chief cause of weakness in columns. He says that " variations of 25 per cent. and over in the elastic limit, as found in these plates and angles, would overshadow those considerations which find expression in empirical formulæ for strength and take no account of such variations."

Other experimenters also have laid much stress on this source of weakness, and there is no doubt that the column is especially sensitive to variation in the quality of the material. This is quite commonly ignored in the design of columns, but a reduction of from 10 to 20 per cent. in the stresses considered safe for tension is good engineering practice.

That the bending stress in the ordinary column perfectly direction-fixed at the ends is equal at the middle and the ends.

It was mentioned in a previous paragraph that the initial curvature greatly modified the distributions of stress in the ordinary column. Here is a case in point. It follows from the ordinary theory that the stress due to bending in the ideal column, fixed in position and direction at both ends, is equal at the middle and ends. In the ordinary column with initial curvature this is by no means the case. When the load is small (and practically speaking over the whole working range) the bending stress at the ends is double that at the centre. As the load approaches the failure point the bending stress at the middle gets more and more nearly equal to that at the ends, until (if this were possible) when W = Euler's limit for the case in question, the bending stress at middle and ends would be the same. In the early stages the column is in practically the same condition as a uniformly loaded beam, direction-fixed at each end.

That there is a tension side in the ordinary practical column.

It is quite common to hear one side of a column referred to as the tension side and the other as a compression side, exactly as in the case of a beam. This idea is quite erroneous, so far as the ordinary practical column is concerned. It is the result of drawings of bent columns in text-books, and photographs of experimental specimens greatly distorted. The actual deflection at the point of failure is very small. For example, in a pin-ended column, 6 ft. 5½ in. long, tested at Watertown Arsenal, $\left(\frac{L}{k} = 47\right)$ the deflection at the point of failure was only 0·067 in.; and in a similar specimen, 24 ft. long, $\left(\frac{L}{k} = 175\right)$ only 0·156 in. The deflection so apparent in published photographs takes place after failure, usually under a much reduced load.

A significant experiment was made at the Watertown Arsenal in 1908. A welded tube, $\frac{L}{k} = 150$, was cut in half, and the two halves merely rested one on the other. In this condition with no connection between the pieces it was tested as a column. The ultimate strength was rather above the average of similar uncut specimens.

That a column with flat ends is fixed in direction at the ends, and that its failure is brought about by the ends " swinging round."

The common view regarding the behaviour of a column with flat ends is that it acts as a column fixed in direction at the ends up to a certain point in its experimental history, at which point the pressure on one edge of the flat surface bearing on the crosshead of the testing machine becomes zero, and if the load be increased, this edge leaves the crosshead, the specimen " swinging round " on the opposite edge, which brings about the failure of the member. This theory, it is believed, was first enunciated by Lamarle in 1846, who determined values for $\frac{L}{D}$ below which " swinging round " would not occur, and above which it was inevitable. It has been revived by a number of others, and is used by Moncrieff as the basis of his formulæ for columns with flat ends.

Many years ago he plotted a number of Hodgkinson's and Christie's deflection curves for specimens with flat ends, and was surprised to find that nearly all these curves exhibited a curious kink at some point in their course. This point had evidently nothing to do with "swinging round," for the deflection, instead of increasing more rapidly, comes to rest, and starts again much more slowly. Further, the original rate of deflection is much more rapid throughout its course than that which subsequently occurs. This behaviour is characteristic of flat-ended specimens, and can be observed in the most carefully conducted experiments. It was evident, on reflection, that the phenomena could be well explained by a theory of imperfect end bearings, and he was led to a somewhat elaborate analysis to explain the matter. Basquin (1913) and others have given similar explanations of the deflection curves of flat-ended members.

The experimental life of such specimens can, in fact, be divided into three stages :—

1st. From the application of the load until the ends bear all over it will deflect as a highly eccentrically-loaded specimen.

2nd. From the moment of complete contact until the maximum load is reached it will behave as a column with position- and direction-fixed ends with an initial curvature. For the first part of this stage the direction-fixing will be negative, which gradually reduces to zero, becomes positive, and increases with the load.

3rd. After the maximum load has been passed, it will continue to deflect, possibly under a reduced load, until the deflection reaches a certain value, when it will "swing round," and the deflection will suddenly increase very greatly.

From an examination of deflection curves it is evident that the first stage may well exceed one-half the experimental life of the specimen, so that if such a column could exist in practice it is evident that it would never be direction-fixed at all, but always act as a highly eccentrically-loaded specimen. Actually, of course, the ends of every column are more or less rigidly attached to other parts of the structure, and the conditions are entirely different, but even in the testing machine it is quite erroneous to suppose that the specimen acts as an ordinary direction-fixed column. Nor is it correct to assume that "swinging round" is the cause of failure. It appears rather to be the result. "Swinging round" may occur under the maximum load, or it may occur long after it. There appears to be a critical value for the deflection. In long specimens the critical deflection occurs before the maximum load is attained, and, to quote Bauschinger, "the preparation for swinging round takes place long before the ultimate resistance is reached." In shorter columns the maximum load is reached first, the specimen deflects rapidly, and swings round usually under a reduced load. Sometimes the deflection is so rapid that the maximum load and "swinging round" occur practically together ; sometimes the critical deflection is never reached, and the specimen remains solidly seated.

There is no definite value for $\frac{L}{k}$ above and below which "swinging round" does and does not occur. Tetmajer reports cases of specimens in which $\frac{L}{D} = 2{\cdot}9$ which rotated on one edge. The theoretical expression for the load at which "swinging round" occurs is certainly not a simple function of $\frac{L}{k}$, but a complicated expression involving initial curvature, radius of gyration, and extreme fibre distance.

That a "solid" column is stronger than a lattice braced column.

It is commonly assumed that a "solid" section, such as a rolled steel joist, or a box section built up of plates and angles, is, area for area, the strongest form of column. This has been completely disproved by experiment, and the ordinary bridge section, consisting of two channels efficiently braced together, has repeatedly shown itself the better section—it may not be the cheaper.

The explanation in the case of the box section is secondary flexure, the plates buckling between the rivets. The strength of built-up sections depends on the strength of the elementary flange columns, and in properly designed columns failure is always the result of local flexure of the flange elements. Now a thin flange plate is far weaker, considered as a column deflecting between two adjacent rivets, than a channel well supported by adequate bracing, and hence the latter type forms the better section.

In the case of rolled steel sections, another factor comes in. It is well known that annealing reduces the strength of columns by lowering the elastic limit, and that thick heavy rolled sections, joists with thick flanges and the like, where the metal cools more slowly, have a lower elastic limit and yield point than a thin plate or section. Hence their resistance as a column is less than that of thinner sections. The recent long series of American experiments again called attention to this point. The designer has to steer between the Scylla of weaker material and the Charybdis of local flexure.

That the ordinary theory of columns has any applicability in practice.

This paragraph is intended to emphasise that the hitherto accepted theory leaves out of account some of the most important factors in the problem, and I believe the column theory of the future will proceed on quite different lines.

The ordinary theory may be said to have originated with the experiments of Musschenbroek in 1729, who found that the strength of his specimens varied inversely as the square of their length. This discovery appeared to conflict with the ordinary beam theory as then understood, and led Euler to his famous investigation, which resulted in the well-known Euler formula. Euler himself was not a little puzzled by his result, and it started a fierce controversy which has never completely died out. The practical men said the theory was nonsense. Their attitude is well expressed by Robison (1822) who characterises Euler's memoirs as a " dry mathematical disquisition " based on assumptions which are " extremely gratuitous," and says that " the most important consequence of the compression is wholly overlooked." He therefore rejects Euler and the speculations " with which he was then amusing himself " as false and useless.

The mathematicians confirmed Euler's results, and gave more rigid and stricter analyses in support, but the objections of the practical men still required an answer. One man, it is true, saw through the question—that somewhat unappreciated genius, Thomas Young—who in 1807 pointed out that the differences under discussion were due to want of agreement between the assumed and actual conditions. Young, in 1807, first gave the correct theory for both eccentricity of loading and initial curvature (given as exercises for students !) and pointed out the now well recognised validity limit of Euler's formula, thus disposing of most of the difficulties.

Possibly owing to his confused and obscure style, the world in general ignored Thomas Young, and proceeded to make experiments—to prove or disprove the correctness of Euler. If all the well-known series of experiments be examined, from Hodgkinson onward (excepting only some of the American experiments), they will be found to be modelled on the Eulerian theory as a basis. Now the Eulerian assumptions, although convenient for the mathematicians, were very difficult to realise in the testing machine, and so experimental conditions have gradually established themselves based upon the theoretical assumptions, but having essential points of difference. Hence have arisen differences between the theoretical and experimental findings, and great pains have been taken to reconcile them ; but in spite of all the disputations, mathematical and otherwise, which the column theory has evoked, the battle of the formulæ still breaks out afresh on occasion, and the merits of this or that expression as an interpretation of experimental results is laboured once more. Meanwhile the dust of controversy has quite obscured the fact that widely as the theoretical and experimental results differ from each other, they both differ still more from the practical member.

The ordinary practical column is a relatively short, initially curved, member, not homogeneous, and usually built up of a number of separate elements. It is usually more or less rigidly connected to the other members of the frame of which it forms a part. It is therefore fixed both in position and direction at its ends, though the fixing is often very imperfect. Due to these quasi-rigid end connections, the column shares the general distortion of the framework, and in consequence has to carry bending moments transmitted through the end conditions. These bending moments are usually of the same "hand," so that S-shaped bending is the rule. The deflection curves usual in text-books have no validity in practice. The magnitude of these bending moments depends on the relative stiffness of the various members of the frame, and still more on the "give" of the connections. They can only be determined by consideration of the distortion of the frame as a whole, and are very difficult to determine theoretically. Nevertheless, I believe that any one with the time and opportunity, who, forgetting the column theory as usually presented, will go to actual structures, and determine from them what actually happens to the members, will find himself in a new, very scantily explored region, and out of such determinations a new column theory will arise founded on practical facts, with frame distortion as the underlying basis.

REINFORCED CONCRETE ROAD AT BRADFORD.

UNDER the direction of Mr. F. Marsden, City Engineer and Surveyor, the Bradford Corporation has recently completed its first length of reinforced concrete carriageway. The length of the road is 450 yds. and the width of the carriageway 27 ft. A considerable length of roadway was laid on filled-up ground with a maximum depth of 20 ft. The filling was left exposed to the weather for a period of nine months and then thoroughly consolidated with a 2½-ton horse roller. The concrete raft is 8 in. thick. The road was laid in two courses; the aggregate for the bottom 6 in. is of 1 in. to 1½ in. local stone and the aggregate of the top layer consists of 2 in. of ¾ in. shap granite. Care was taken not to weaken the concrete by the use of too much water. The proportions of the concrete were, in the bottom course, 4 : 2 : 1, and of the topping 3 : 1½ : 1. The local stone was broken on the site by a mechanical breaker and the dust used as fine aggregate. The fine aggregate of the 2 in. topping consisted of washed river sand. The whole of the concrete was mixed by machine close to the site and conveyed to the bed by a motor jubilee wagon, with a capacity of of about 1 cu. yd. The surface was finished slightly corrugated by means of the tamper which was 3 in. wide, giving corrugations of the same width.

The method of construction was as follows:—The bottom layer of reinforcement was rolled out about 50 ft. and raised on short lengths of iron piping 1½ in. diameter. The bottom 6 in. of concrete was then laid and well tamped between the wires of the fabric. When the concrete had reached the requisite height the top reinforcement was carried forward and the 2 in. of granite topping laid on. The concrete was laid in stages of approximately 3 ft. at a time for the full width of carriageway, the 2 in. topping being placed in position before the initial set had commenced, thus ensuring a good bond between the two layers. The surface was then tamped with a wooden hand tamper spanning the full width of the carriageway.

At the completion of each day's work the end was protected by a stunt-end board and finished flush at the top, leaving about 3 ft. of the bottom concrete projecting. This surface was well washed down before the next day's work was commenced, and the top 2 in. cut back for a distance of about 6 in. to ensure a good face joint. The majority of this work was carried out during the winter months, during which time the surface was protected from frost by being covered with tarpaulins until the concrete was sufficiently hard to be covered with 3 in. of sand. This covering was kept constantly wet for four weeks. The reinforcement consisted of B.R.C. Fabric No. 9 in the lower course (1½ in. from the bottom), and B.R.C. Fabric No. 14 in the top course (2 in. from the finished surface).

The road was opened to traffic after the concrete work had been completed eight weeks, and the surface left without any covering for three months, during which period heavy traffic passed over the road. A census showed that over 1,500 vehicles passed over the road during the period of 8 hours. No sign of cracking or failure in any way has been observed.

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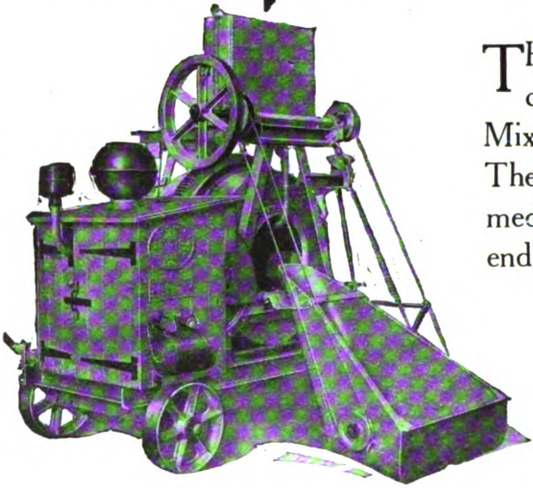

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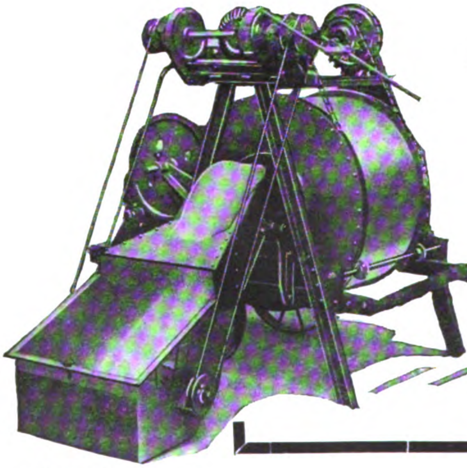

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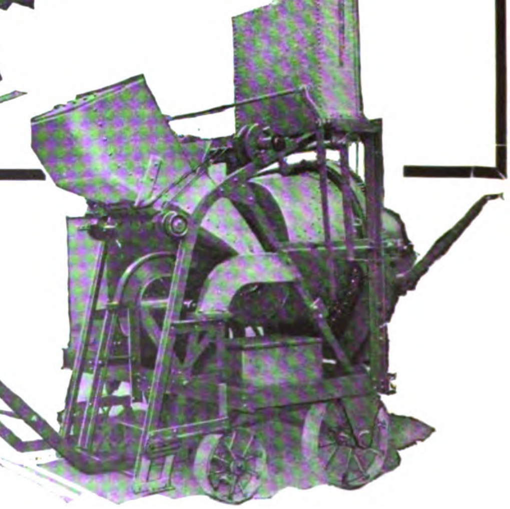

MODEL No. 5.
Mixed Capacity
5 Cubic Feet.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ½ in. mesh	,,	15	0
Best British Portland Cement	per ton 58s. to	63	0
"Ferrocrete" Portland Cement	10s. per ton extra		

Boarding for Shuttering—

		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £24 per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £25 ,, ,,

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
7/16 in. to ½ in. Rounds	,,	13	6
⅜ in. Rounds	,,	14	6
¼ in. Rounds	,,	15	6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed with Clean Water in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per yard cube	45	6
Do.	do.	in columns	,, ,,	50	6
Do.	do.	in beams	,, ,,	50	6
Do.	do.	in floor slabs 4 in. thick	per yard super	5	4
Do.	do.	in floor slabs 6 in. thick	,, ,,	7	11
Do.	do.	in floor slabs 9 in. thick	,, ,,	11	6
Do.	do.	in walls 6 in. thick	,, ,,	8	2

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	24	0
,, 7/16 in. to ½ in.	,,	23	0
,, ⅝ in. to 2⅞ in.	,,	22	0

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*;. 1¼-in. rods, 3½*d.*

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.*

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	55	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	51	0
Do. do. in small quantities	per ft. super	0	9½
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last, in narrow widths	,, ,,	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	,, ,,	1	1
Do. do. as last, in narrow widths	,, ,,	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are those current in the London area, namely:—Carpenters and joiners, 1/8 per hour; Labourers on building works, 1/3; Operators on concrete mixers and hoists, 1/4.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

MEMORANDA.

PROSPECTIVE NEW CONCRETE WORK.

ABERDEEN.—*Road.*—The Streets and Roads Committee is considering a scheme for the construction of a new road from Castle Street to the Bathing Station.

AYR. — *Esplanade.* — The T.C. has decided to commence the construction of a new sea wall and esplanade at Blackburn foreshore, estimated to cost £12,000.

BIRMINGHAM.—*Bridges.*—The Corporation proposes to construct eleven new bridges.

BIRMINGHAM.—*Road.*—The M.H. has promised to contribute 60 per cent. of the cost of the construction of a new road from Birmingham to Wolverhampton, which is estimated to cost £573,000.

BLEADON. — *Bridge.* — The Somersetshire C.C. has a scheme on hand for the construction of a new bridge over the main road at the Bleadon and Uphill railway station, estimated to cost £9,000.

BRADFORD.—*Road.*—The Corporation proposes to construct a new road from Odsal to Rooley Lane.

BRIDLINGTON. — *Bathing Pool.* — The Corporation has approved a scheme for the construction of a bathing pool, estimated to cost £6,000.

CAMBRIDGE.—*Road.*—The T.C. has applied to the M.H. for sanction to borrow £13,000 for the construction of a road from Newnham Road to Trumpington Road.

CARMARTHENSHIRE. — *Bridge.* — A scheme for a new bridge over the River Towy has been recommended for approval.

CHESTERFIELD.—*Street.*—The Corporation proposes to construct a street from Tontine Road to Park Road.

CLEETHORPES. — *Bathing Pool.* — The U.D.C. has applied for sanction to borrow £21,124 in connection with a bathing pool scheme.

CONGRESBURY.—*Bridge.*—The Somersetshire C.C. has decided to construct a bridge over the river at Congresbury, at an estimated cost of £6,500.

DEWSBURY.—*Sewage Works.*—The Corporation has applied to the M.H. for sanction to borrow £201,000 in connection with the completion of the sewage works at Mitchell Laithes.

DUDDINGSTON.—*Road.*—The Government has sanctioned a loan of £9,400 by the Edinburgh Corporation for the purpose of constructing a new arterial road from Piershill to Duddingston.

DURHAM.—*Bridge.*—The Durham C.C. proposes to construct a new bridge at Sunderland Bridge, near Durham, at an estimated cost of £56,000.

EASTBOURNE. — *Road.* — The Eastbourne and Hastings Corporations are in negotiation for the construction of a new road between the two towns, estimated to cost £500,000.

CONCRETE SWIMMING POOL AT A COUNTRY CLUB.

FRINTON.—*Sea Wall*—The U.D.C. has applied to the M.H. for sanction to borrow £10,000 for the construction of a mass concrete sea wall.

GURNARD.—*Road.*—The Cowes U.D.C. proposes to construct a new road, at a cost not exceeding £15,000.

HERNE BAY.—*Sea Wall.*—The U.D.C. has decided to apply for a loan for the construction of a sea wall.

HINCKLEY.—*Sewage Works.*—The U.D.C. has applied to the M.H. for sanction to borrow £34,400 for sewage and sewage disposal works.

KIRBY.—*Sewage Works.*—The Tendring R.D.C. has applied to the M.H. for sanction to borrow £6,000 for sewage and sewage disposal works for the parish of Kirby-le-Soken.

LAMBTON.—*Bridge.*—The Durham C.C. proposes to construct a new bridge at Lambton, at an estimated cost of £52,000.

LEATHERHEAD.—*Bridge.*—The Southern Railway Co. has applied for parliamentary powers to construct a bridge in Leatherhead over a proposed new permanent way.

LINCOLN.—*Road.*—The City Council has applied to the M.H. for sanction to borrow £10,489 for the construction of a road from Boultham Park Road to Rookery Lane.

MONKWEARMOUTH.—*Bridge.*—The T.C. has approved the construction of a new bridge between Sunderland and Monkwearmouth, at an estimated cost of £300,000.

NORTHWOOD.—*Gas-Holder Tank.*—The Pinner Gas Co. proposes to construct a new gas-holder tank with a capacity of 60,000 cu. ft.

NORWICH.—*Compensating Tank.*—The Corporation proposes to construct a new compensating tank at the Heigham works, at an estimated cost of £2,950.

NOTTINGHAM.—*Bridge.*—The Nottinghamshire C.C. has a scheme on hand for the construction of a bridge over the Trent between Nottingham and Newark, estimated to cost £125,000.

SANDGATE.—*Sea Defence Works.*—The U.D.C. has applied for a loan towards the cost of sea defence works.

SEATON.—*Promenade.*—The U.D.C. has approached the M.H. for sanction to borrow £4,250 for the construction of the eastern promenade, supported by a sea wall.

TYNEMOUTH.—*Bathing Pool.*—The T.C. proposes to construct a bathing pool at the south end of the Long Sands.

UFFINGTON.—*Bridge.*—The R.D.C. proposes to construct a new bridge at Wilsthorpe.

WITHERNSEA.—*Sea Wall.*—The Improvement Committee recommends the construction of a concrete sea wall on the west side of the south promenade.

WORCESTER.—*Bridges.*—The Corporation proposes to construct three bridges.

TENDERS ACCEPTED.

HALESWORTH.—*Wall, etc.*—The U.D.C. has provisionally accepted the tender of Messrs. Howard Bros., at £235 12*s.*, for the construction of a concrete wall, fencing, and paving.

KINGSBURY.—*Sewage Works.*—The U.D.C. has accepted the tender of the Standard Construction and Maintenance Co., Ltd., at £6,784 16*s.*, for the construction of a sewage disposal works.

LONAN, I.M.—*Concrete Wall, etc.*—The Highway Board has accepted the tender of Messrs. Creer Bros., Douglas, at £999 10*s.*, for the construction of a reinforced concrete wall and culvert at Garwick Bridge.

LONDON (HACKNEY).—*Foundations.*—The L.C.C. has accepted the tender of Messrs. Rowley Bros., West Green, N.15, at £1,747, for foundation work in connection with the construction of a new school on the Holcroft Road site.

LONDON (WANDSWORTH).—*Foundations.*—The L.C.C. has accepted the tenders of Messrs. G. E. Everitt & Sons, at £1,633, for foundation work in connection with the construction of the extension to the Town Hall; and Mr. A. Monk, Lower Edmonton, at £8,665, for foundation work in connection with the erection of the Wandsworth Technical Institute.

MICKLEOVER.—*Sewage Works.*—The Repton R.D.C. has accepted the tender of Mr. G. F. Tomlinson, at £9,778 11*s.* 9*d.*, for the construction of sewage and sewage disposal works at Mickleover.

NOTTINGHAM.—*Reservoir.*—The T.C. has accepted the tender of Messrs. Matthews and Mumby, Ltd., Manchester, for the construction of a new reinforced concrete reservoir at Colwick Hill.

PLYMOUTH.—*Walls, etc.*—The T.C. has accepted the tender of J. W. Spencer, St. Lawrence Yard, Plymouth, for the construction of concrete walls, etc., in connection with the extension of the coal store at the electricity works.

PORTSMOUTH. — *Concrete Store.* — The T.C. has accepted the tender of Messrs. F. Bevis, Ltd., Portsmouth, at £2,239, for the construction of a reinforced concrete store.

TAUNTON.—*Sewage Works.*—The Corporation has accepted the tender of Messrs. F. & E. Small, Taunton, at £23,129, for the reconstruction of the sewage disposal works.

WINDSOR. — *Tank.* — The T.C. has accepted the tender of Mr. A. Watson, Ascot, at £385, for the construction of a concrete water-tank and pump-house.

WOLSINGHAM.—*Culvert.*—The Weardale R.D.C. has accepted the tender of Mr. J. J. Reed, Frosterley, at £1,274, for the construction of a reinforced concrete culvert, 90 ft. long, 9 ft. wide, 14 ft. high, on the road from Wolsingham to Tow Law.

[*** Other tenders accepted are given on pp. 179 and 180.]

RECENT PATENT APPLICATIONS.

200,512.—S. J. Boussiron: Reinforced concrete bridges.

202,642.—Dorr Co., Inc.: Apparatus for preparing and mixing cement.

205,970.—J. S. McNay: Reinforcement for concrete.

206,446.—Internationale Siegwartbalken-Ges.: Method and device for the production of hollow articles such as tubes and poles from reinforced concrete.

207,803.—R. H. Rogers and T. Perry: Concrete roofs and partitions.

207,915.—J. M. Hall: Moulding ferro-concrete building slabs.

208,342.—A. C. Manifold: Shuttering and apparatus for the erection of concrete buildings.

208,465.—A. Melville and D. MacDougall: Bending-machines for reinforcing rods.

208,652.—F. Werth: Shuttering for casting concrete.

208,742.—F. J. Brougham (D. Moir and H. Buchanan): Joints for concrete pipes.

208,958.—Internationale Siegwartbalken-Ges: Reinforced-concrete pipes.

209,186.—W. Dunstan: Cementitious composition for manufacturing into plaster sheets and moulded articles.

209,688.—T. Furniss and J. B. Farren: Pre-cast concrete slabs for floors and roofs.

210,012.—E. Hirsch: Reinforced-concrete constructions.

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

APRIL 1924 VOL. XIX. No. 4

A MONTHLY JOURNAL for Engineers, Architects, Surveyors and Contractors and all interested in Cement, Concrete, Reinforced Concrete, Fire-Resisting Construction and Structural Steel.

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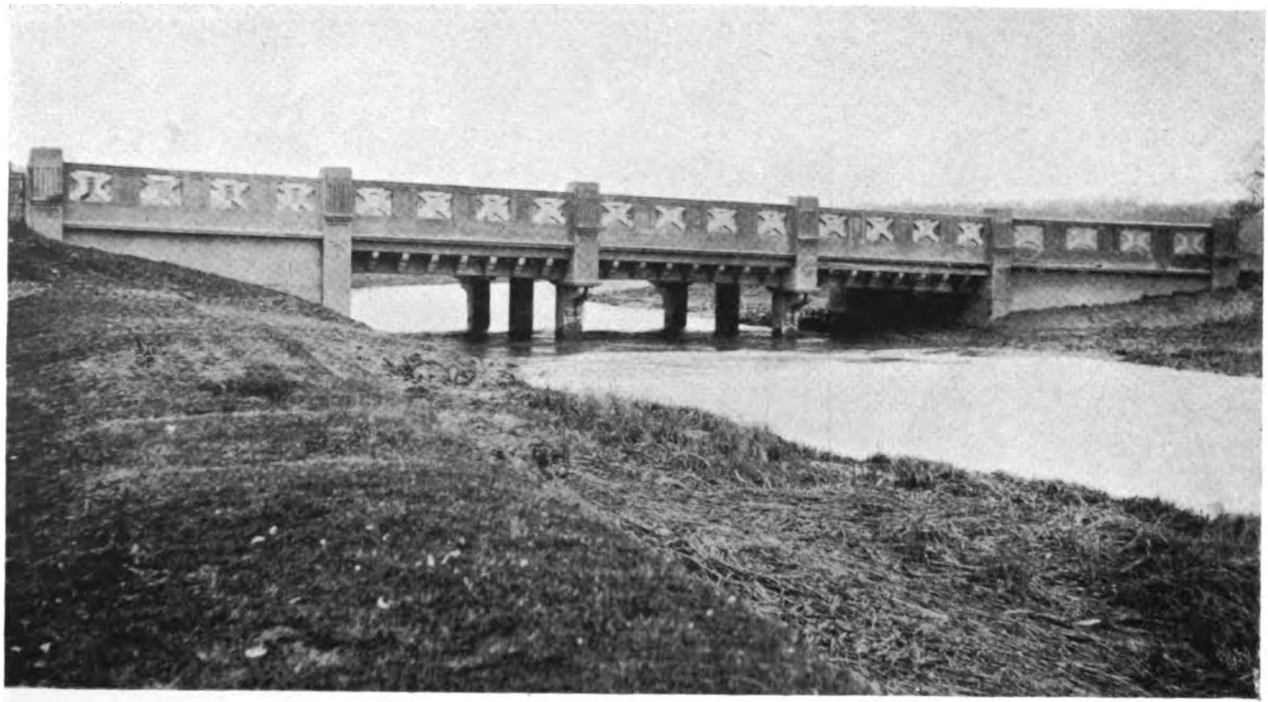


[Mr. W. H. Morgan, A.M.Inst.C.E., County Surveyor

FINGRINGHOE BRIDGE, ESSEX: BUILT WITH ALUMINOUS CEMENT.
(*See page* 213).

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIX. No. 4. LONDON, APRIL, 1924

EDITORIAL NOTES.

A REAL HOUSING PROBLEM.

Two events of a few days ago shed a great deal of light on the difficulty of providing housing accommodation.

(1) Mr. Lumley asked the Minister of Health, " What is the annual output of bricks in this country, and what number of bricks would be required to build 200,000 houses ? " To which Mr. Wheatley replied : " The present output of bricks is variously estimated at between 2,500 million and 4,000 million a year. Taking 20,000 as the average number of bricks per house, a total of 4,000 million bricks would be required for 200,000 houses." The position therefore is that even taking the higher figure of 4,000 million, there are only sufficient bricks being made to carry out the Government's housing programme of 200,000 per annum. If no other buildings were required the position would be a fairly sound one, but it is obviously impossible to use every brick manufactured for the erection of working-class dwellings. Schools, hospitals, larger houses, etc., must be built, and so must new industrial and commercial buildings, or the tenants of many of the new houses would possess comfortable homes only at the cost of loss of employment. Thus, at the present rate of production, it is quite impossible for the housing programme to be carried out in brick.

(2) The Departmental Committee appointed by the Government to Survey the Prices of Building Materials issued its report for the months of January and February. In setting out the prices of materials in different localities, the only comment the Committee makes is as follows : " Between December and January there were no appreciable changes of general application to which attention need be drawn, but it will be seen [from the statistics in the report] that since January there have been advances in the price of bricks, ranging from 6*d*. to 5*s*. per thousand at Bristol, Manchester, Newcastle, Swansea and Glasgow. It is further reported from Swansea that the supply of bricks is limited."

Thus the shortage of bricks is influencing prices, and apart from the sheer impossibility of carrying out the whole of the housing programme in this material, the report of the Departmental Committee indicates that an attempt to erect any considerable number in this material can only result in higher prices. In addition to this the shortage of skilled labour has to be contended with, a shortage which was frankly admitted by the leaders of the trade unions last month.

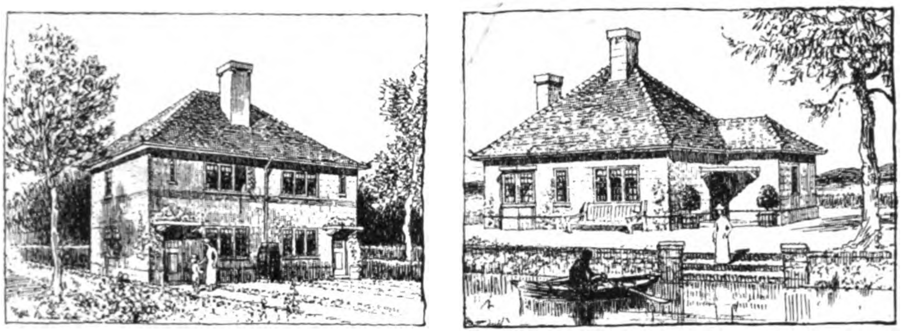
In view of these statements made by the Minister of Health and contained in the Report of the Departmental Committee, and the many thousands of satisfactory concrete cottages which have already been in occupation for a number of years, it would seem that no further arguments in favour of concrete cottages are necessary. Many very large new housing schemes are now being erected in concrete, and it is probably hardly too much to say that concrete must be looked to as the principal material for the provision of working-class houses.

CONCRETE AT WEMBLEY.

We have heard the British Empire Exhibition at Wembley referred to as " the apotheosis of concrete," and we gather from his recent lecture, reported in this issue, that Mr. Maxwell Ayrton, F.R.I.B.A., who, with Mr. John W. Simpson, PP.R.I.B.A., is the architect for the Exhibition buildings, is of the same opinion. Mr. Ayrton's experience in designing these buildings has led to an enthusiastic appreciation of concrete as a material for the erection of monumental buildings : " Reinforced concrete," he said, " not only opens up possibilities but demands a treatment entirely its own, and at first it is a shock to find walls of incredible thinness, arches equally thin and apparently without the necessary abutments, staircases hanging in the air, and so forth. The enormous facilities of the material will undoubtedly be a danger to its development in design. . . . Gradually, and in its own proper time, will it find its own, and forms inconceivable at the present time will presently be as satisfying to the eye as they would at the moment appear incongruous and fantastic." The increased interest which architects now take in the material cannot but have beneficial results. Mr. Ayrton's lecture was full of suggestions as to methods by which the design of reinforced concrete might be improved, and will well repay careful study by all interested in the material.

CONCRETE AND FIRE-RESISTANCE.

We have always considered the study of concrete to be a subject of great interest, but we did not imagine that such interest would develop into excitement until we read a leading article entitled " Concrete and Fire Insurance " which recently appeared in a contemporary. The following extract from the article will explain : " Now I quite agree that steel and concrete can produce a fire-proof building —but only up to a certain point. When that is reached, then indeed concrete becomes a most terrible agent for spreading a fire with fearful rapidity. The real cause is that a certain degree of heat not usually attained simply boils the water in the suspension, and then indeed the concrete loses all its fire-resisting properties and the surface bubbles up. Many years ago I saw this on a small scale in Victoria Street, Westminster, when a fire had started in what was supposed to be a fireproof pile of business offices. I saw a floor vaunted to be fireproof all blisters, many of great size, and some penetrating to the floor below, all due to what was nothing but the fact that the water suspended in the concrete had become a frightful furnace and had boiled the suspended water. Above I have



[*T. Raffles Davison, Hon. A.R.I.B.A., delt.*

DESIGNS FOR A PAIR OF CONCRETE COTTAGES AND A CONCRETE BUNGALOW: FROM "CONCRETE COTTAGES, BUNGALOWS AND GARAGES." (*See p.* 217.)

shown how largely water enters into concrete, and, as present-day buildings run into ever-increasing dimensions, is it not likely that we may have to face tremendous conflagrations? I have here written on that heavy building with concrete includes a peril at present but little guessed."

Bubbling concrete! Blisters which penetrate! Water becoming a frightful furnace! Here were new features of concrete which had been overlooked. Concrete fireworks seem now a possibility; why not a special display at Wembley to celebrate the centenary of the invention of Portland cement? The conversion of water in concrete into "a frightful furnace" suggests a new source of fuel economy which would put an end to the terrors of higher coal prices and miners' strikes. Immediate investigation became imperative, but all our efforts to reproduce the bubbling and blistering phenomena by submitting concrete to the action of fire have failed, and we can only conclude that such sights as our contemporary's contributor describes are reserved for the mystics and do not come within the ordinary man's vision. Perchance, however, what was seen at the Victoria Street conflagration was the bubbling and blistering of an asphalt covering to a concrete floor.

If the article we have referred to is on behalf of anti-concrete propaganda we are content. It is sufficiently ludicrous to defeat its own ends, and illustrates the dearth of evidence against concrete as a fire-resistant. But the article shows that the educational stage in connection with concrete is still incomplete and needs to be commenced on a more elementary basis than has hitherto been thought necessary.

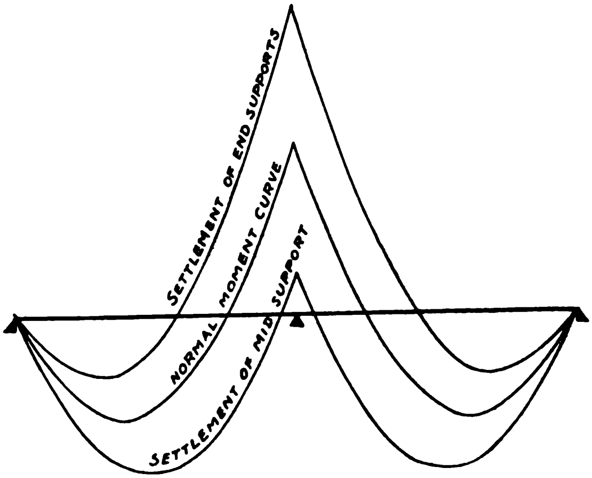


FIG. 1.

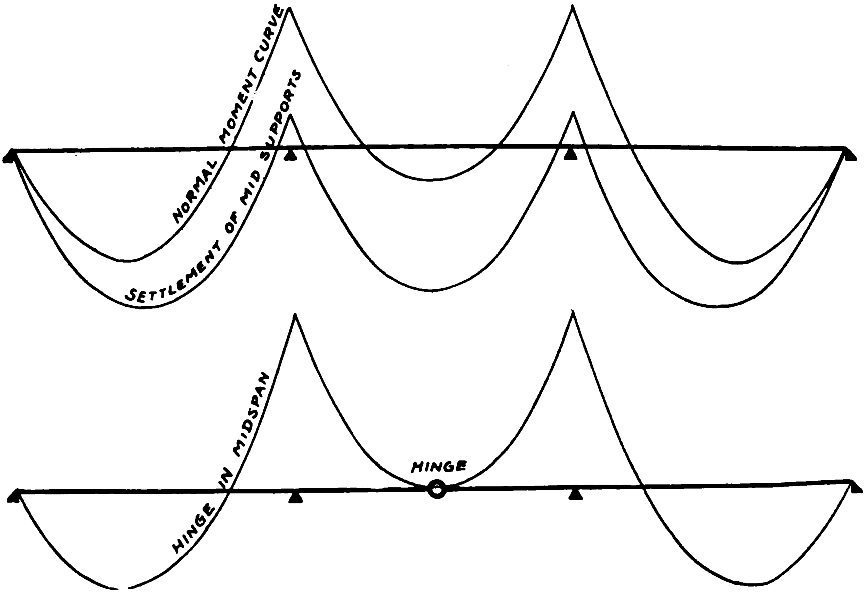


FIG. 2.

HINGES IN REINFORCED CONCRETE STRUCTURES. (*See p.* 207.)

HINGES IN REINFORCED CONCRETE STRUCTURES.

By R. N. STROYER, B.Sc., M.I.Mech.E.

REINFORCED concrete is a material which, generally speaking, invites the full use of continuity owing to its monolithic nature, and in most cases this feature is taken advantage of, as a better utilisation of the material is thereby obtained. The structures thus designed are from a statical point of view indeterminate, and their calculation involves the use of the theory of elastic deformations or of the principle of least work, which of course means a little extra trouble to the designer but usually also a saving in material. The design being based upon certain assumptions in regard to continuity and fixity, it is naturally of the greatest importance that these assumptions hold good, as otherwise the calculations may be useless and the structure unsafe.

If, for instance, the abutments of an arch are not immovable, the assumptions for calculating the arch with fixed ends do not obtain, and it would be dangerous to do so. If, similarly, some of the supports for a continuous beam do not remain at the original level, but settle during the loading of the beam, the assumptions for calculating the latter as continuous are not at hand, and the beam, if calculated as such, will probably fail. To start with, the sign of such a failure is generally a crack, which, if allowed to develop, may result in destruction; the inference to be drawn from a crack is usually the presence of tension in the concrete, not provided for by suitable reinforcement.

Except in rare cases, where the cracks are due to pure tension or shear in the member, it may be said that the appearance of cracks generally indicates a bending moment too great to be taken by the section in question; the section being too weak, the stresses become high enough for a crack to occur, which further weakens the section and leads to further development of the crack, and so *ad infinitum* until destruction occurs. That the bending moment becomes too great for a section in a correctly-designed indeterminate structure is due to failure of the assumptions as to supports, continuity, fixity, etc., the effect of which is that some of the members that are calculated to take certain forces or moments do not actually do so, or only to a smaller extent than calculated, with the result that other members that were to be relieved by the former become overloaded accordingly. If, for instance, in a uniformly loaded continuous beam over two spans the assumption fails as to the middle support keeping level with the end supports, and a settlement takes place of the former, the negative moment over this support does not reach its calculated value and the two positive mid-span moments are therefore not relieved to the extent calculated, but increase correspondingly, with the result that the mid-section may be overloaded and fail. If, on the other hand, the two end supports settle in relation to the middle support, the two positive mid-span moments do not reach their calculated value and therefore do not relieve the negative moment over the support as calculated, so that this latter increases in value and may become so great as to cause cracking and failure (*Fig.* 1).

When a crack forms in a section it is generally a sign that the latter is overloaded, and if the crack is allowed to develop the tensile reinforcement may be stressed beyond the elastic limit and begin to flow; that this happens need not necessarily mean a collapse of the section itself or the adjoining members, as the latter may be strong enough to stand the new conditions set up by the formation of the crack; the section is no longer able to withstand or transmit moments, but it may still be able to resist or transmit shear or normal forces—it may, in other words, be acting as a hinge.

The characteristic of a hinge is the ability to transmit normal and tangential forces but not moments. If a cracked section is still able to act as a hinge a new statical condition obtains, the structure being less indeterminate than before. Taking the example of a three-span continuous beam where the middle span is being overloaded as a result of settlements of the middle supports, a crack forming at mid-section may be able to act as a hinge, if for instance, the section is doubly reinforced, and the structure is thereby made less indeterminate, and with a new moment curve as shown in *Fig.* 2. The new statical condition will now relieve the mid-section of any positive moment, but at the cost of imposing greater negative moments over the supports, the mid-span now consisting of two simple cantilevers; if the beam is strong enough to resist these increased negative moments no failure need take place. In this way an indeterminate structure is often saved from failure by the formation of a natural hinge, the effect being always to reduce the indeterminacy of the structure; this may go on until the indeterminate structure is reduced to a terminate one, when a further crack or hinge means failure; e.g. a simply supported beam or a simple cantilever would fail by the introduction of a hinge at the over-loaded section, viz. the mid-section of the simply supported beam or the springing section in the cantilever. While natural hinges in an indeterminate structure may save the latter, there are disadvantages that do not encourage the use of them; the appearance is generally unexpected and the formation of the hinge itself is irregular and generally leads to some destruction of material in the section; further an unprotected crack will, in time, lead to the total destruction of the reinforcement in the section.

It is therefore always preferable to provide a proper hinge in all cases where there is reason to suspect that the conditions may, in time—through settlements of the supports or other causes—lead to the formation of a serious crack. Thus, in cases of uncertain foundations, etc., it is usual to allow for any contingencies by introducing hinges or, in other words, making the structure as nearly statically determinate as possible, in which case the structure is not so susceptible to settlements of the foundations.

An example of the formation of a natural hinge as described above is shown in *Fig.* 3, where the crown of an arch bridge is seen to have cracked badly; in this case the nature of the crack was so serious as to involve the condemnation of the bridge. The crack bears evidence of a negative bending moment that the crown section is unable to sustain. Assuming that the arch is correctly designed as a hingeless structure, this condition might be brought about by failure of the assumptions as to fixity of

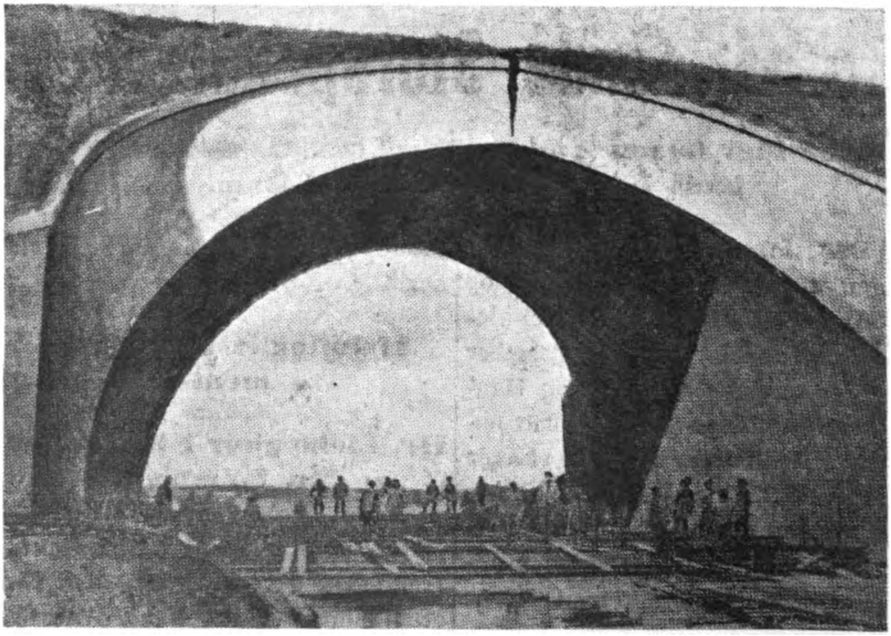


Fig. 3.

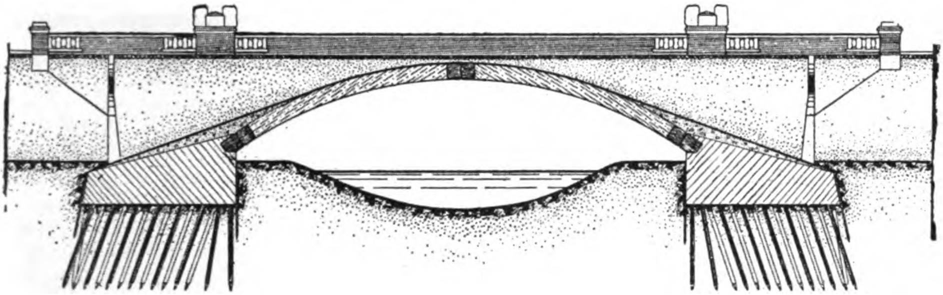


FIG. 4.

the supports; a horizontal movement of the abutments, for instance, might be caused by the earth pressure on the back of the latter exceeding the assumed value, or by the ground itself being unable to provide a fixed and immovable support.

The actual construction of the hinges follows the usual practice employed for steel and masonry structures, and the hinges may be formed either in steel, stone or concrete; special attention must be devoted to the effective bonding of the hinge with the adjoining concrete member so that the former may be able to transmit all the normal and tangential forces from the latter; it will often be found that extra reinforcement is required to enable the concrete to take the forces in question as the section of the concrete member generally decreases towards the hinge where, theoretically, the section is narrowed down to a knife edge.

As an example of structures where hinges have been introduced to neutralise the effects of settlements may be mentioned the arch bridge shown in *Fig.* 4. The ground, as indicated by the pile foundations, is unreliable, and incalculable movements of the abutments may be expected; the introduction of three hinges, however, makes the arch statically determinate and therefore impervious to movements of the foundations—within reasonable limits. The hinge construction is carried out in stone, and the hinges at the springing are covered by mass concrete to facilitate the drainage of the arch ring.

A number of three-hinged arches have been executed in reinforced concrete, the hinges generally being composed of a pair of steel castings bearing upon a steel roller pin. A typical example of a hinge of this description is shown in *Fig.* 5.

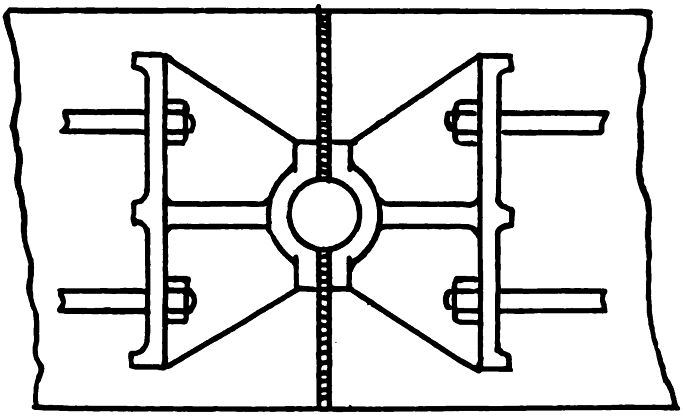


FIG. 5.

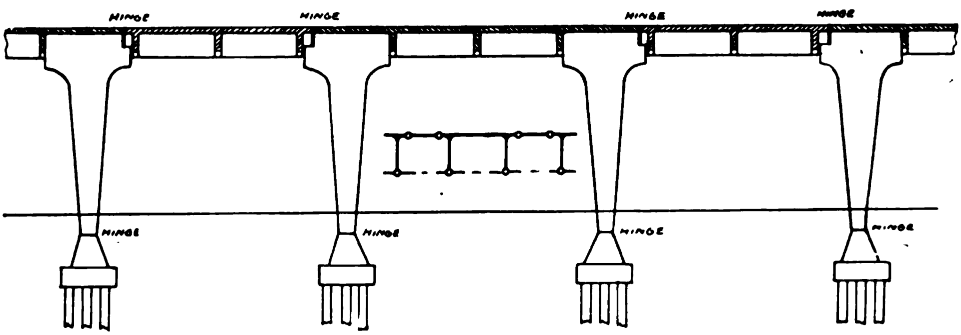


Fig. 6.

Where the hinge is not called upon to transmit other than transverse forces, a very simple construction in concrete is possible, as will be seen from *Fig.* 6, which illustrates a form of hinge used on a long viaduct where considerable difficulties were encountered with the foundations. Owing to the unreliable nature of the ground a series of hinges was introduced, splitting up the whole length of the viaduct into groups of single stiff frames with cantilever ends on which short girders found their bearings; the latter girders are simply supported, and the stiff frame, which is calculated as being hinged at the bottom, has only one statically indeterminate reaction which may be taken up internally without relying upon the foundations. Considerable settlements can therefore take place without causing any destructive cracks, such as would otherwise have appeared in a continuous hingeless structure. The hinges in this case further obviate the necessity of expansion joints.

A form of hinge which has the advantage of being extremely simple and cheap is arrived at by the consideration that a natural hinge will form at a predetermined section in a structure if the section in question is so designed as to be incapable of resisting any bending moments; if at the same time the section is provided with means for transmitting normal and tangential forces, the formation of a natural hinge may be anticipated without any apprehensions as to failure or destruction of material. If in a reinforced concrete member the reinforcing steel is placed in the middle of the section the latter becomes practically useless for resisting tension in the extreme fibres such as are produced by bending moments, and a section where the reinforcement is so placed offers very little resistance to any bending but may still be capable of transmitting normal and transverse forces.

A glance at *Fig.* 7 will show the principle of this type of hinge; the reinforcing bars *r* and *r'* are carried across the section to the opposite side and intersect in the middle, so that section A-A is devoid of reinforcement in the extreme fibres, and therefore does not resist bending moments to any degree compared with the adjoining sections. The worst that may happen to the section is

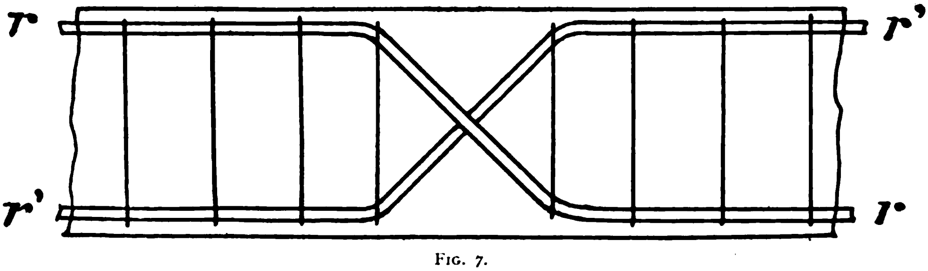


Fig. 7.

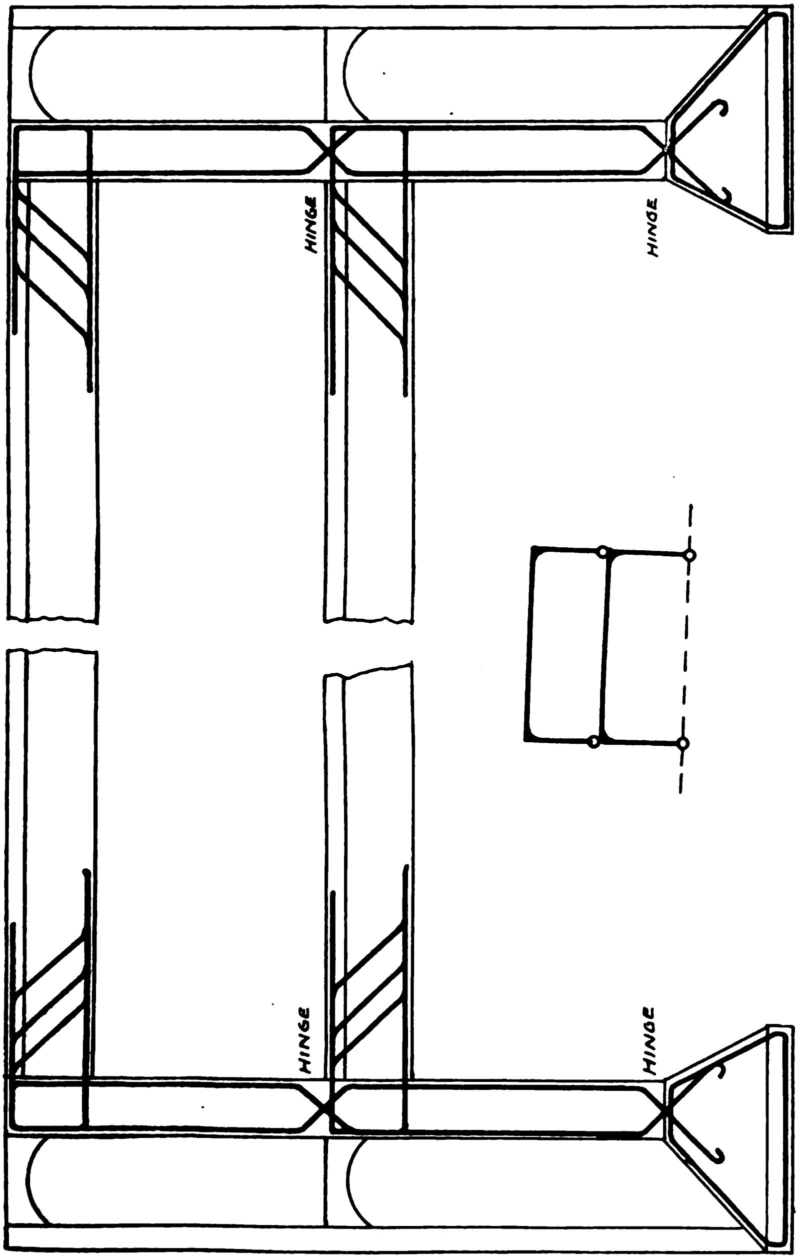


FIG. 8.

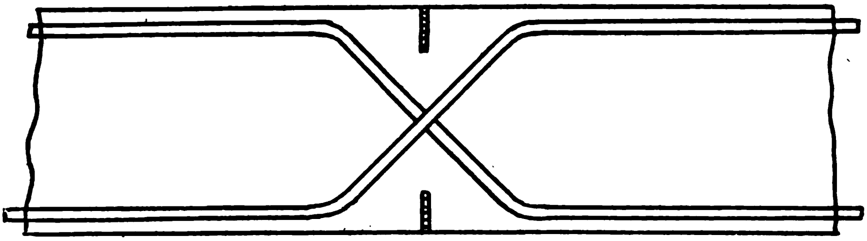


FIG. 9.

that a crack may form in the extreme fibres on the tension side, if the movement due to the hinge action is excessive, and therefore this type of hinge should not be used where considerable movements are anticipated ; with the ordinary very small angular movements that usually take place in a reinforced concrete structure, all that happens in this kind of hinge is that the movement is located and confined to this particular section as being the weakest to resist angular deflections, and with the very minute turning movement that is necessary to constitute the presence of a hinge neither the compression nor the tension in the opposite extreme fibres need have any destructive effect on the concrete.

This form of hinge is sometimes seen in Continental designs, and as its use dates back a good many years and has proved satisfactory, actual practice would appear to confirm the correctness of the theoretical considerations that have led to its adoption.

Fig. 8 shows an example of such a hinge in a stiff frame consisting of two heavy columns connected by horizontal beams at the top and in the middle. The structure forms part of a reinforced concrete cinema at Portsmouth described in the issue of this journal for January, 1923, and in the ordinary way the combination of columns and beams would form a double stiff frame ; statical considerations led to the introduction of hinges at the bottom of each of the posts, constructed in the manner just described ; the angular movements in this case are so small that no cracks have formed or will ever appear. Even in cases with excessive movements where a crack may form, it is more than unlikely that it would ever extend in depth to the middle of the section so as to lay open the steel to the influence of atmospheric conditions ; as a means of affording protection against this contingency and at the same time secure a clean cut opening, a division plane may be introduced during the pouring of the concrete by placing strips of sheet lead or similar material in the form as shown in *Fig.* 9.

FINGRINGHOE BRIDGE, ESSEX.

ALUMINOUS CEMENT IN BRIDGE CONSTRUCTION.

By LAURENCE T. WEASER, M.S.E., M.I.Struct.E.*

SITUATED near the south-east boundary of the Borough of Colchester is a hamlet named Fingringhoe, the non-main road from which to Colchester was formerly carried over the Roman River by an old timber bridge, which, like many similar structures, had been for a long time in a dangerous condition and quite inadequate for even the small amount of traffic using this district road.

The old bridge has now been replaced by a "Hennebique" ferro-concrete structure (*see* Frontispiece), designed by the County Surveyor, Major William H. Morgan, D.S.O., A.M.Inst.C.E., assisted by the author, in conjunction with Messrs. Mouchel & Partners, the contract being carried out by Messrs. W. & C. French, Ltd., of Buckhurst Hill.

The superstructure is divided into three bays formed by four rows of piles, each row consisting of three 20 in. by 20 in. hollow piles, which carry three main continuous beams, 15 in. by 21 in. deep, giving 20 ft. clear spans between piles. These main beams are given a 3 in. camber, and were designed with a gradient of 1 in 45, uniform with the new roadway; they are 8 ft. 9 in. apart and carry secondary cross beams 6 in. by 15 in. deep, the outer end of each projecting beyond the external main beams, and thus forming cantilevers to carry footpaths and parapets; a 6-in. raft completes the floor of the bridge, on which an average thickness of 8 in. of rough concrete is placed to form a foundation for the finished road surface, consisting of 3-in. of tar macadam.

Fig. 2 shows the shuttering and steel rods for beams in position.

The parapets are 9 in. thick with main

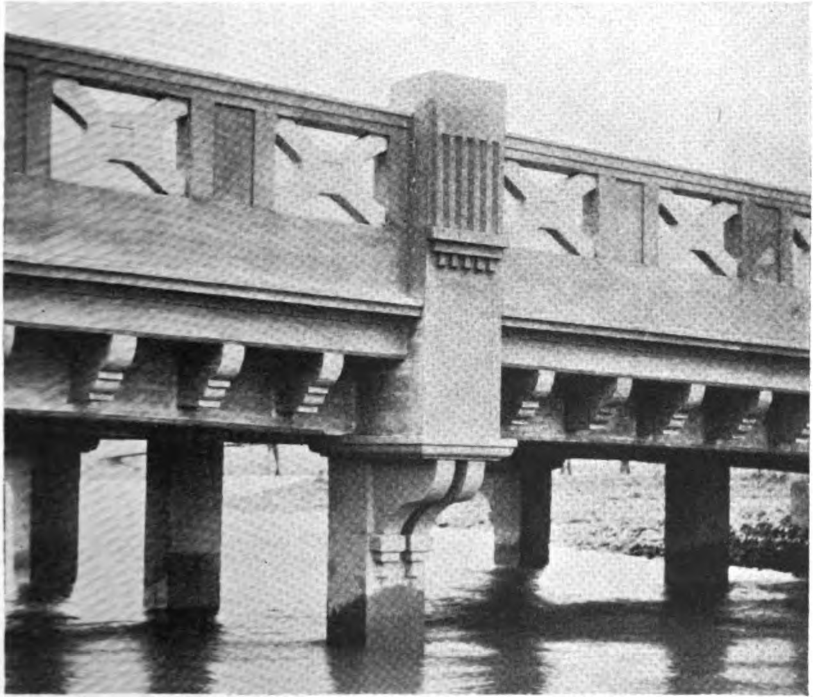


FIG. 1.—DETAIL OF PARAPET AND BRACKET.

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* Bridge Engineer, County Surveyors' Department, Essex.

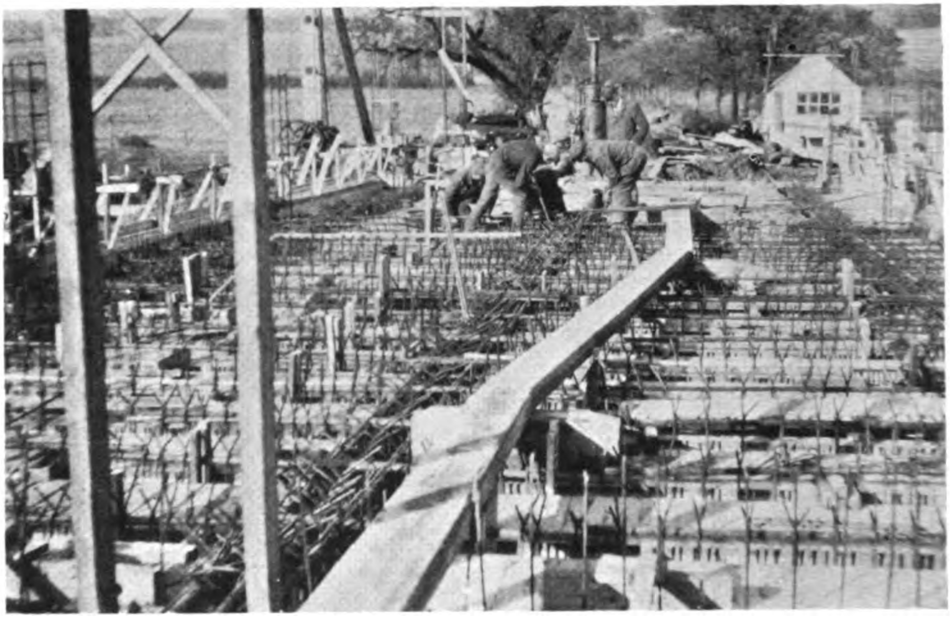


FIG. 2.—SHUTTERING AND REINFORCEMENT FOR BEAMS IN POSITION

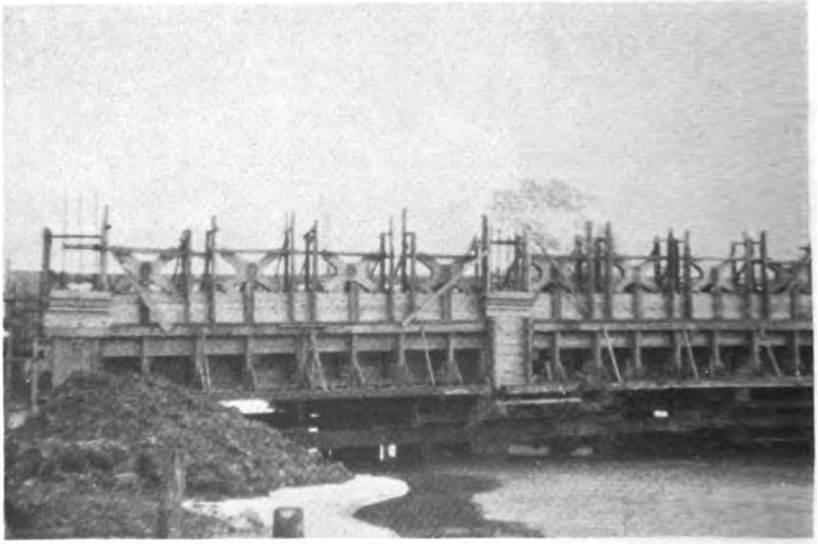


FIG. 3.—SHUTTERING FOR PARAPETS.

piers carried on brackets connected to the piles (*Fig.* 1), cross-braces being pre-cast and placed in position when the shuttering for the parapets was executed (*Fig.* 3).

The bridge has a clear width between parapets of 24 ft., giving an 18-ft. carriage-way, with a 3-ft. footpath each side.

The abutments are formed by 6-in. curtain walls, connected to beams 20 in. by 30 in. deep placed at raft level and beams 20 in. by 12 in. deep placed 2 ft. below the bed of the stream. These beams are fixed to the three piles driven at each end, and thus the whole structure is carried on twelve piles (average length, 40 ft.), which were driven to a set of 5 in. for one hundred blows from a 2-ton monkey falling 3 ft. 6 in.

Fig. 4 shows the steel skeleton of the wing walls, which are 20 ft. long and built on floating foundations entirely detached from the main structure, so as to allow any movement of these walls, owing to the unsatisfactory nature of the subsoil, to take place without cracking the bridge proper. It might be mentioned that the north-west wing wall has already moved ⅞ in.

The concrete was mixed in the proportion of 1 cwt. cement, 1⅛ cu. ft. sand, 3⅜ cu. ft. ⅜-in. crushed aggregate, and 2¼ cu. ft. ¾-in. crushed aggregate. With the exception of the cross-braces the whole of the concrete work was carried out with *ciment fondu* as the matrix. This proved highly satisfactory, and enabled piles to be driven within 48 hours from the time of casting; hence the piles were cast on the driving platform (*Fig.* 5) and allowed to mature while the gantry and engine were being moved to the new position, this process usually taking just over a working day.

The greatest care was exercised in forming the moulds and shuttering, which consisted of wrought grooved and tongued boards, with the result that when stripped the lines of cornice, mouldings and arrises were perfectly clean and sharp, thus obviating the necessity for rendering or cement washing.

The first pile was cast on August 24, 1923, and the last one driven on October 1, 1923, the bridge being tested and opened to traffic on January 30, 1924.

Although this bridge was designed to carry the Ministry of Transport's Standard Load, it was deemed impracticable to attempt bringing such heavy loads through this narrow country lane with the probability of tearing the road to

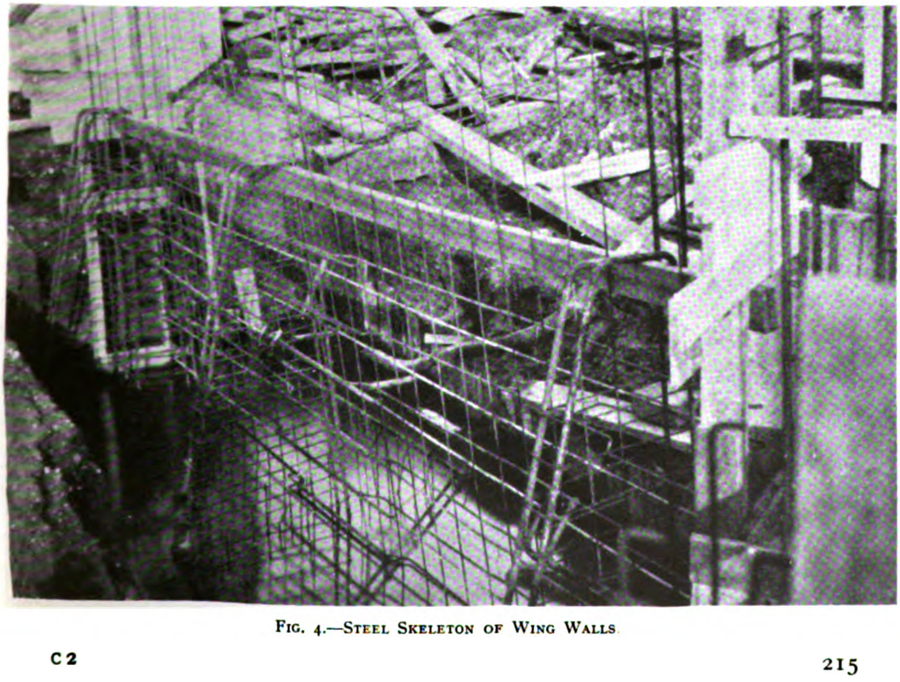


FIG. 4.—STEEL SKELETON OF WING WALLS.

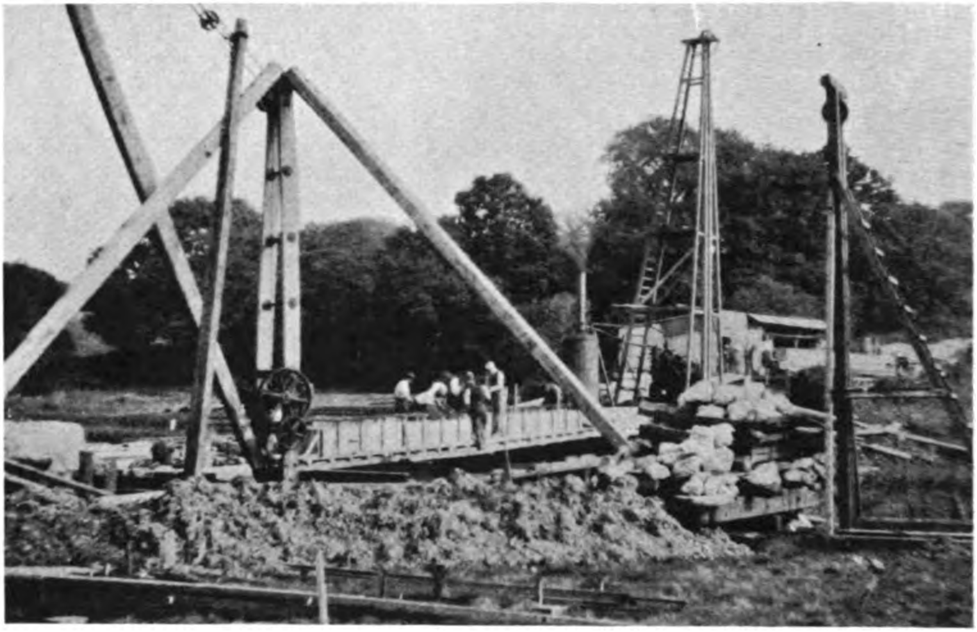


FIG. 5.—PILES CAST ON DRIVING PLATFORM.

pieces, and therefore the test loads consisted of a 10-ton steam roller and 14-ton and 13-ton steam lorries, which passed over the bridge and were packed on the centre of each span, the maximum deflection recorded during these operations being 0·014 in., or one-seventeenth-hundredth part of the span. The instrument used for recording the deflections has only recently appeared on the market, and is known as the "Metrocline," designed by Colonel H. T. Tudsbery, M.C., M.Inst.C.E. Not only were deflections obtained in the usual way by placing the instrument on an independent staging with the point of deflection rod pressing against the soffit of the beam, but in the indirect manner by placing the instrument on a support fixed to the beam itself.

Extensive reference to aluminous cement has not been made, as the practical use of this cement will be the subject of a future article.

THE HOUSING PROBLEM.

A NEW BOOK ON CONCRETE COTTAGE CONSTRUCTION.

As has been shown by paragraphs in recent issues of this journal, concrete is being used on a considerable number of housing schemes of local authorities under the Housing Act of 1923, and a large number of others are now under consideration. A study of these schemes reveals the fact that most of those which are being carried out in concrete are large propositions involving hundreds of houses, and that where small numbers of concrete houses are being built in every case the contractors are firms who specialise in this method of construction. It appears the builder who has always built in brick is often chary of changing his materials and adopting methods to which his workers are not accustomed. It is significant, however, that in the majority of cases where tenders are submitted by different firms for brick and concrete construction the latter is invariably lower, and one of the obstacles in the way of a fuller advantage being taken of the economy of concrete is undoubtedly the fact that comparatively few builders quote for this method of construction. The reason for this is, as already stated, that builders are not always disposed to change the materials to which they and their workers are accustomed for a material which they may still regard as something in the nature of an experiment—the demand for cheap houses to a very considerable extent remains unsatisfied because of the lack of training in concrete work offered by the building schools throughout the country.

With a view to in some measure help the architect and builder interested in the production of cheap houses to a more thorough knowledge of the methods necessary for the design and erection of small concrete buildings, we have published a second edition of Mr. Albert Lakeman's book, "Concrete Cottages, Bungalows, and Garages." This is an entirely new work, and is an exhaustive

[*T. Raffles Davison, Hon. R.I.B.A., delt.*

DESIGN FOR A GROUP OF CONCRETE COTTAGES: FROM "CONCRETE COTTAGES, BUNGALOWS AND GARAGES."

treatise on the subject of concrete cottage construction. Mr. Albert Lakeman, M.S.A., M.I.Struct.E., Hons. Medallist (Construction), has had a very large experience in the design and erection of all classes of concrete buildings, and his own knowledge of the subject and the experience gained by others in the construction of small concrete buildings are embodied in this book in such a form that this type of building can be erected without further assistance. Seven designs for cottages, bungalows and garages, with different accommodation, have been specially designed by the author for construction in concrete, and with each design is given (1) All the information necessary for its erection, (2) Perspective drawings showing the same designs with flat and pitched roofs, (3) Plans, (4) Sections, (5) Full working drawings, and (6) Detailed bill of quantities.

The completeness with which these designs have been worked out has not been done with any view to supplanting the architect, and all who wish to have a house built for them, or builders engaged to erect concrete houses, are strongly advised to consult an architect. But the book is also written for architects, and it is realised that with a comparatively new material such as concrete, in which a large number of architects have as yet had no experience as a medium for the construction of a complete building, it is necessary that there should be a book which will help the architect in the design of such buildings. To get the best results out of the material it is not sufficient simply to use concrete in place of bricks. Concrete has many characteristics of its own. Whether the method of construction be monolithic, piers and slabs, or concrete blocks, the system or the units employed are vastly different from the standard size brick, and call for corresponding differences in design; it is in order to point out what is possible in this direction that the designs for various types of cottages, bungalows, and garages have been elaborated, in the hope that the book will in some measure set a good standard of design for this type of building.

The Minister of Health announced in the House of Commons a few days ago that estimates of the annual production of bricks in this country ranged from 2,500 million to 4,000 million, and that the Government programme of 200,000 houses per annum would by itself require 4,000 million bricks. Thus even if the highest estimate be correct the production of bricks will suffice only for the Government houses, and as other essential factories, warehouses, better class houses, etc., must be built it is obvious that it will be impossible to build all the State-aided houses in brick. As, therefore, it will be necessary to adopt alternative methods of construction if the programme is to be carried out, the present seems a particularly opportune time for those interested in the provision to study the possibilities of concrete for this purpose.

With a view to getting the advantages of small concrete dwellings known as widely as possible, this volume, which is copiously illustrated in the text and contains drawings by Mr. T. Raffles Davison, Hon. A.R.I.B.A., and coloured plates, is being published in two editions, one strongly bound in cloth at 5*s.* net (by post 5*s.* 6*d.*), and one in paper covers at 3*s.* 6*d.* net (by post 4*s.*). The book is now ready, and copies may be ordered by filling in the order form on p. xxiv.

REINFORCED CONCRETE TANK AT THE TOP OF THE NORTH TOWER OF THE CRYSTAL PALACE.

A PARTICULARLY interesting piece of reinforced concrete work has just been completed at the Crystal Palace, where a reinforced concrete water tank has been installed at the top of the North Tower. These well-known towers were erected to the designs of Brunel in 1854, and it says much for the quality of the iron plates of which they were built that the Tanks stood without signs of leakage from that date to 1918. As will be seen from the illustration on pp. 220-221, in order to take the weight of the water from the floor of the tank to the sides of the tower, Brunel designed the floor as a dome.

In 1918, however, the iron plate tank was found to be perforated and leaking about 12 ft. from the bottom, and this hole was repaired by means of a piece of plate and angle irons secured to the outside vertical tee irons of the tank.

In 1921 it was evident that the tank plates were badly corroded, and a thorough examination was decided upon; and Mr. Freeman, of Sir Douglas Fox & Partners, then made a survey. In order to preserve the stability of the tower the consulting engineers decided that the water level in the tank should not be reduced below 18 ft. (or about 500 tons of water), and the recommendations in their report were more or less based on the assumption that the condition of the tank plates below that level was at any rate no worse than the then exposed plates above that level.

The recommendations in the report called for the entire emptying of the tank, and it consequently became necessary to provide the equivalent of 500 tons of water in some other form. Thus, whatever scheme for the rebuilding of the tank were decided upon, a large weight would be needed in the bottom of the tank in order to take the place of the water when it was emptied, and it was decided, by demolishing the derelict cycle track, to serve the double purpose of obtaining aggregate for mass concrete to provide the necessary weight and clear away the track. The latter was accordingly broken up, conveyed to a concrete breaker at the foot of the tower, hoisted to the top, and disposed in the following manner.

A platform was erected on the twelve permanent radial girders at the top of the tank, and on this was placed about thirty tons of broken aggregate and fifty tons of sand. Another platform covering the whole area of the tank was constructed at a height of 20 ft from the bottom. This platform was carried by thirty-six 10 in. by 5 in. rolled steel joists arranged radially and suspended from the tops of the outer and inner walls of the tank by means of wire ropes passing over saddle blocks, the ends of the ropes being secured respectively to the outside vertical tee-irons with strong shackles and to a specially-made ring placed on the stiffening plate surrounding the flue which passes up through the middle of the tank as shown in the section on pp. 220–221.

On this platform a further 340 tons of concrete aggregate was placed in a bin so constructed that the material was banked against the outer wall of the tank and a space reserved round the flue about 7 ft. in width on which the mass concrete forming the foundation of the tank was afterwards mixed. The balance of the required 500 tons dead weight was made up by about 60 tons of cement on the ninth floor and about 20 tons of plant and scaffolding.

These ballasting arrangements having been completed the tank was emptied, and a further survey showed that the condition of the lower plates was much worse than anticipated, and could not be relied on for the retention of water.

In the light of this disclosure, the consulting engineers advised the erection of, and prepared the design for, an entirely new tank of reinforced concrete constructed within the old tank and resting on a bed of mass concrete of special construction filling up the lower part of the tank to a height of 14 ft.

The mass concrete for the bottom of the tank was then prepared, being composed of 1 part Portland cement, 2 parts sharp sand, and 6 parts coarse material from the cycle track, hitherto used as ballasting.

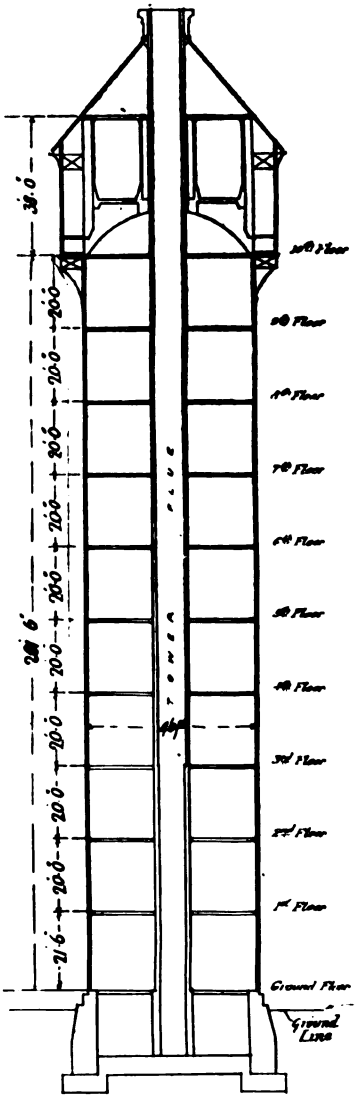
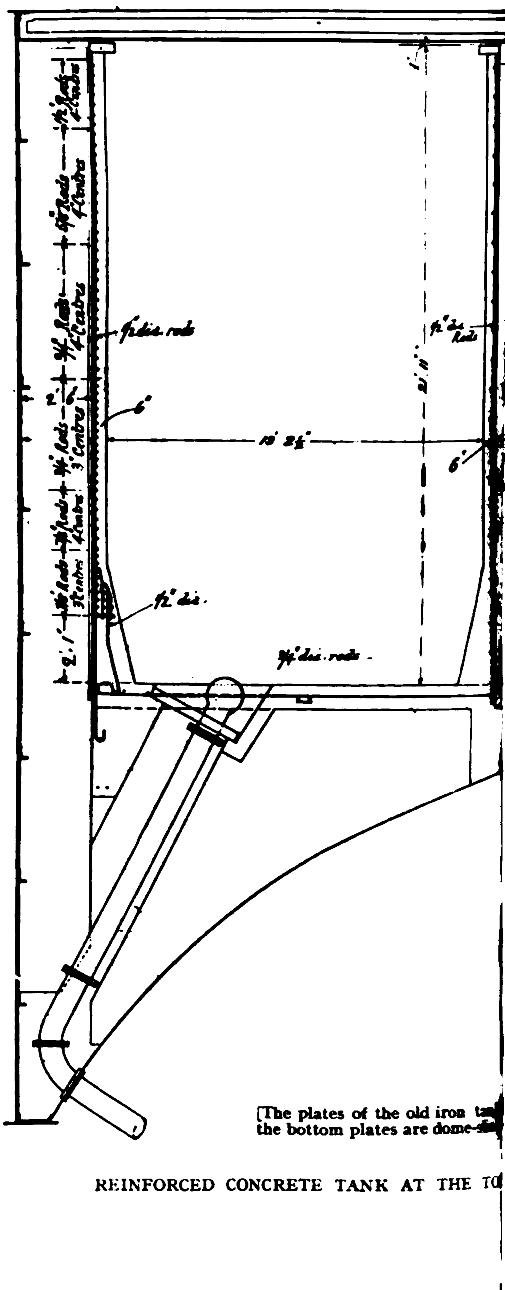
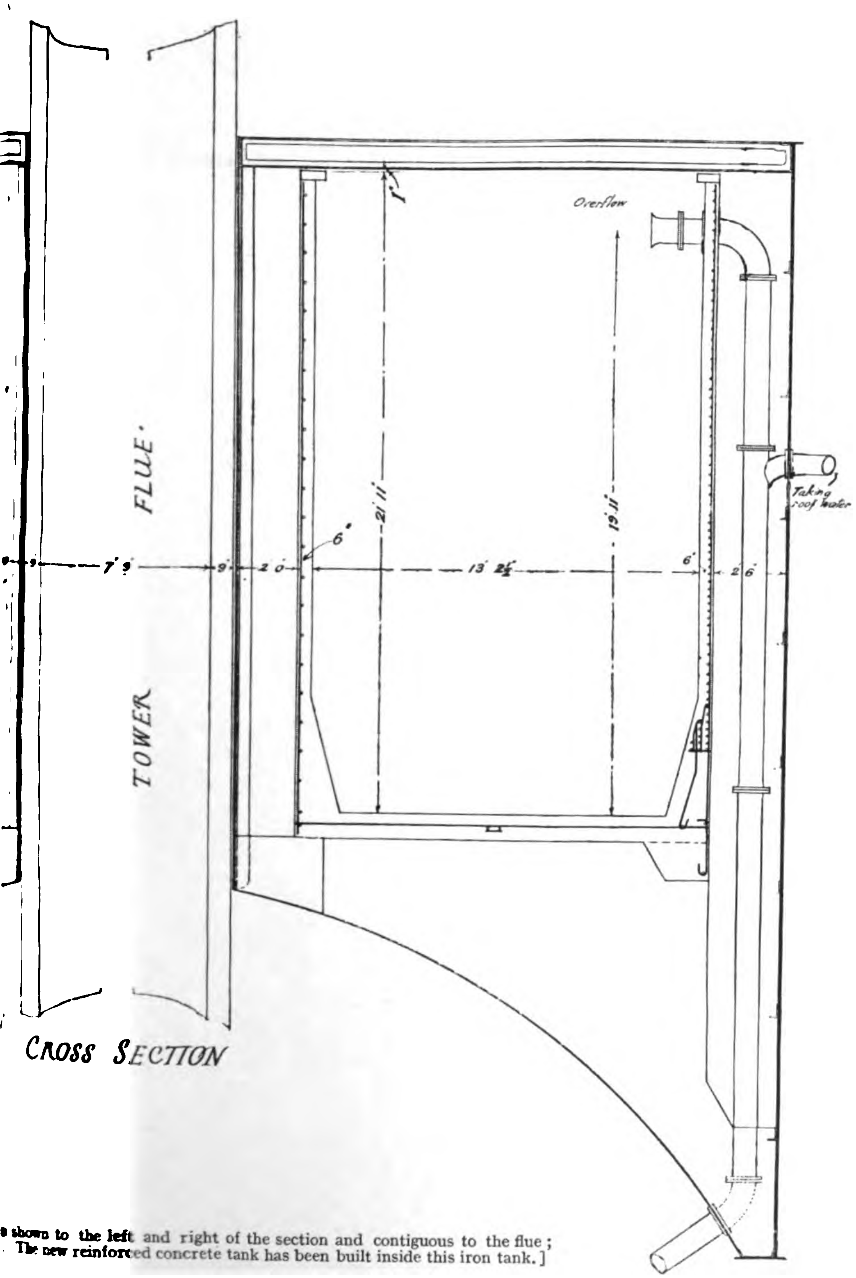


DIAGRAM SECTION OF TOWER.



[The plates of the old iron ta
the bottom plates are dome-s

REINFORCED CONCRETE TANK AT THE TO



shown to the left and right of the section and contiguous to the flue ;
The new reinforced concrete tank has been built inside this iron tank.]

THE NORTH TOWER, CRYSTAL PALACE.

In depositing the concrete provision was made for passages or manholes to take the main pipes through which the water enters and leaves the tank ; these manholes were covered at the level of the tank bottom with cast-iron covers, a portion of each cover being removable to permit access to the pipe joints.

The mass concrete having been deposited and the large platform emptied of the aggregate from the cycle track, the platform was re-arranged for the purpose of constructing the tank. This operation was considerably complicated by the presence of the flue passing through the centre of the tower.

Twenty-four of the 10 in. by 5 in. joists were raised and placed between the twelve permanent radial girders at the top of the tank, and still suspended at the outer ends by the wire ropes, in the bights of which posts were placed. At the inner ends the wire ropes were removed and bolts substituted, the latter passing through the eye-bolts to which previously the wire ropes had been attached.

Four large platforms, suspended from the 10 in. by 5 in. joists, were then constructed as bunkers and filled with sufficient materials for the lower part of the tank (about 120 tons in weight), the balance of the material (about 80 tons) being placed on platforms supported on the radial girders at the top of the tank.

From the suspended bunkers and the bunkers on radial girders at the top of the tank hoppers were constructed to feed a concrete mixer placed on the floor of tank and to replenish the suspended bunkers from the top supplies. The concrete mixer was of 2½ cu. ft. capacity, electrically driven.

Shuttering for the reinforced concrete walls was constructed as follows :—For the outer side of the outer wall of the tank the shuttering was made in twelve circumferential sections, each 4 ft. in depth, in two tiers and arranged to pass and rise above each other as the work advanced ; heavy supporting posts being fixed under each of the twelve permanent radial girders. Shutters of similar depth and construction, but in six circumferential sections, were made for the face of the inner wall next the flue, with posts as for the outside wall.

The shutters for both inner faces of the tank were similar to those used for the outside faces, but only 12 in. in depth to facilitate the deposition of the concrete and the necessary tamping round the reinforcement. Six tiers were prepared for each inner face.

The wall reinforcement consisted of round rods from ⅞ in. to ½ in. diameter, placed in position and wired together. It was suspended during erection from a circular frame fixed to radial girders, and distance pieces were inserted at each post to keep the reinforcement in its true position—these being taken out as the work proceeded. The floor reinforcement was temporarily supported from the mass concrete on wooden blocks, which were also removed as the work went on. A plan of the floor is given on pp. 236-7.

It should be mentioned that the shuttering was allowed to remain in position for three days after the deposition of the concrete, and on its removal the faces of the walls were liberally sprayed from a rose several times a day until the tank was eventually filled with water.

During the period occupied in carrying out the preparations for concrete laying exhaustive experiments had been made with various grades of aggregates and cements to decide the most suitable mixture producing a satisfactory and water-resisting concrete for the tank. It was eventually settled to adopt the following mix :—1 part of " Ferrocrete B," specially made for the purpose, 1½ parts of Ham river sand, 1 part of washed ballast passing a ⅜-in. ring down, and 2 parts of washed ballast passing a ¾-in. ring down.

Gauge boxes were made for each class of materials, which were first mixed together dry before being fed into the mixer, into which had previously been placed 2¼ gallons of clean water. In this connection and as instancing the extreme care with which this work was carried out, it may be mentioned that only town water was used in the mixing, to obtain which it was necessary to run special supply pipes to the top of the tower and provide pumping plant and tanks. The men working the mixing machine were supplied with a sand glass timed to a minute-and-a-half to ensure the proper mixing of the concrete.

The deposition of the concrete bottom was started from the outside wall in about 3-in. layers, working round the tank and towards the inner wall.

The outer wall was built in a similar

manner simultaneously with the formation of the bottom, so that no layer of concrete was allowed to harden before another was added. As four hours was considered to be the longest period that the concrete would remain green, the work was arranged to proceed continuously night and day, the start being made at 8 a.m. on October 8, last year. The construction proceeded day and night till the evening of November 1, when the concreting was completed with the exception of the splash coping which was considered necessary owing to the oscillation of the tank which takes place during high winds. It is of interest to note that the expansion of the metal framework of the tower in the summer months amounts to about ¾in. in its height. The expansion is greater on the south side of the tower than on the north side owing to that side being exposed to the sun, and this fact also affected the laying of the concrete as it was found that that laid on the south side set much more quickly than the concrete laid on the north side of the tower.

About a week after the completion of the concreting water was pumped up, but it was found that some percolation took place through the lower part of the outer wall on the southern side of the tank. The bottom and inner wall were found to be sound.

This percolation was apparently due to the bad adhesion of the layers, which was considered to be the resultant effect of a short period of unseasonably warm sunshine striking on that side of the tank and unduly accelerating the setting of the concrete.

The defective places were localised and thin grout forced in with excellent results, as when water was again, after a reasonable interval, pumped into the tank the proposed maximum height of 18 ft. was reached without measurable leakage and remained at that level for five weeks, when the tank was again emptied for the purpose of clearing away scaffolds and platforms used during the construction.

The time occupied from the commencement of the work to the filling of the tank was about three months. An inspection of the site and an appreciation of the difficulty of hoisting the materials to the top of the tower (250 ft. above ground level), of the cramped space within which the work was carried out entirely by artificial light, and of the cold weather experienced during the carrying out of the work, show that this was a very creditable performance on the part of Mr. W. Wright, the Engineer to the Crystal Palace, and his staff, who prepared the detail drawings and supervised the whole of the work, which was carried out by the Crystal Palace workmen. We understand that the tank at the top of the South tower is to be similarly replaced by a reinforced concrete tank in the near future.

BOOK REVIEWS.

"Specification." Edited by Frederick Chatterton, F.R.I.B.A.
(London: The Architectural Press. Price 10s. 6d.)

The twenty-sixth edition of this publication comprises over 600 pp., and maintains the reputation it has achieved as a standard work of reference for architects, surveyors, engineers, and all interested in building. In addition to a mass of valuable information on all the trades connected with building, there are special articles on "Hotels and their Equipment," by Mr. Stanley Hamp, F.R.I.B.A., "Half-Timber Construction," by Edwin Gunn, A.R.I.B.A., "Inexpensive Timber Roofs," by A. E. Astor, "The Submission of Plans to Local Authorities," by H. Kenchington, A.R.I.B.A., and "The New Housing Act," by the Editor. Although called "special articles," they are much more comprehensive than that title implies, and are, in some cases, the most complete treatises on their subject which have been published; Mr. Hamp's article on hotels, for instance, covers every aspect of the subject, and is fully illustrated with plans and photographs of some of the most modern hotel buildings at home and abroad. The "Concreter" section runs to over 70 pages, and although it contains much useful data, there are one or two suggestions which, if adopted in future editions, would make it more complete. For instance, architects and engineers are advised to have details of reinforced concrete prepared for them by specialists, but although the methods of firms who sell reinforcements and erect buildings are given, no mention is made of the large body of *consulting* engineers who specialise in reinforced concrete work. It is recommended that cement be spread to a depth not exceeding 2 ft. on a floor for a period of not less than 14 days and turned from time to time, whereas the bulk of expert opinion is in favour of storing the cement in as deep a heap as possible in order to prevent too great an exposure to air and consequent absorption of moisture.

Resistance of the Zone of Tension in Reinforced Concrete Structures which are subject to Bending.

By Otto Graf (Part D. 40 pp., 27 illustrations and 2 Tables. Berlin: Wilhelm Ernst & Sohn. Price 72 marks.)

THIS small, yet well-illustrated booklet is one of the reports published by the German Committee on Reinforced Concrete. It is based on experiments made in 1906–1921 in the Stuttgart Testing Station. The tests were made on a beam rather more than 7 ft. long, supported on two " knife edges " exactly 6 ft. 6½ in. apart, the changes in length of the central 28 in., with variations in the load, being accurately measured. It was found that the beam first began to crack on the under-side when the tensile strength of the iron in the zone of tension was exceeded. The cracks first formed in those parts of the beam farthest from the reinforcement. The tests showed the great importance of keeping the concrete moist throughout until no appreciable effect of the water could occur. Beams kept in a dry state directly after manufacture give lower results than those which had been properly cured. It was also found that, unless the beams were kept sufficiently wet, even a large proportion of cement did not greatly increase their strength. The addition of Rhenish trass has a small beneficial effect on the strength of the beams. Transverse bars in the reinforcement had no useful effect ; on the contrary, they appeared to be somewhat harmful.

Speaking generally, the results of measuring the more important tension effects were as anticipated, but for details it is, of course, necessary to study the diagrams and tables very carefully. The booklet is in the German language.

Resistance des Materiaux. By Bertrand de Fouviolant.

Paris : J. B. Bailliere.

THIS is one volume in a series of " Grand Industrial Encyclopædias," published under the patronage of the Society for the Encouragement of (French) Industry. The treatment of the subject of the Strength of Materials is analytic and graphic. The elastic properties of various materials are considered at length, as are also the dynamic effect of external forces of various kinds and the effect of various displacements. The mathematical treatment of the strength of beams is particularly good, but the volume as a whole is only of service to those with a good knowledge of the calculus and facility with engineering and mathematical terms in French. Those who have this knowledge and the time and inclination to give this volume the careful attention it deserves will find it both interesting and helpful. Unlike some French engineers, the author has not confined himself merely to a logical explanation of the various theories and laws which form the basis of all such works, but has taken special pains to proceed as rapidly as possible to practical application. This mode of treatment gives the work a special value for those engineers for which it is chiefly intended. Unfortunately, there is no index.—A. B. S.

Sell's Directory of Registered Telegraphic Addresses.

(London : Business Dictionaries, Limited. Price 45s.)

THE thirty-ninth edition of " Sell's Directory of Registered Telegraphic Addresses," just published, contains the names, alphabetically arranged, of some 100,000 firms in Great Britain and Ireland, together with their postal address, telephone number, trade or occupation and registered code word. The code words are all alphabetically arranged in another section, so that the addressee can immediately identify the sender of a telegram, even though the message be signed, as is frequently the case, by a registered code word only. A Trade Section is included in which the names and addresses of 130,000 firms are classified under 3,500 trade headings. In the issue of the current year a new departure of interest to the building trade is to be found in a separate section which gives, under 500 trade headings, the names and addresses of the leading firms engaged in the building and allied trades in Great Britain and Ireland.

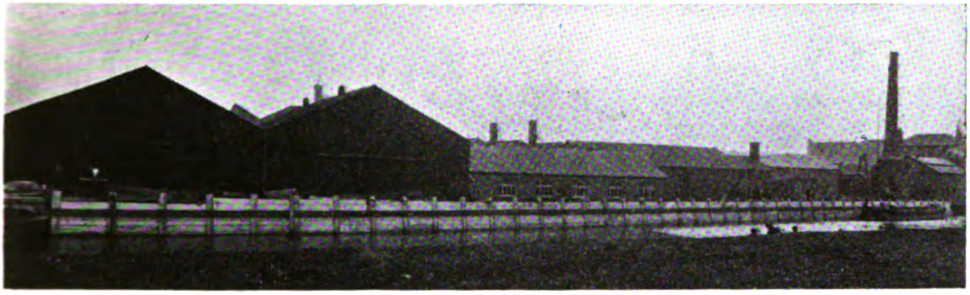


FIG. 1.—REINFORCED CONCRETE WALL AT ABBEY MATCH WORKS, APPROACHING COMPLETION.

FLOOD PREVENTION WORKS ON BARKING CREEK.

IN consequence of serious damage caused by the exceptional high tides of November, 1921, which flooded the premises of Messrs. J. John Masters & Co., Ltd., match manufacturers, situated on the left bank or east side of Barking Creek, that Company decided to take such steps as would prevent a recurrence of such an event. Not since 1904, a period of seventeen years prior to the acquisition of the property by Messrs. Masters, had such a great height of tide been reached, nor any flooding of the site been caused. Although such an abnormal rise of tide is very infrequent it is liable to occur at any time, and valuable machinery and expensive raw materials and chemicals are liable to destruction or damage.

Acting upon the advice of Mr. A. Havelock Case, M.Inst.C.E., Messrs. Masters

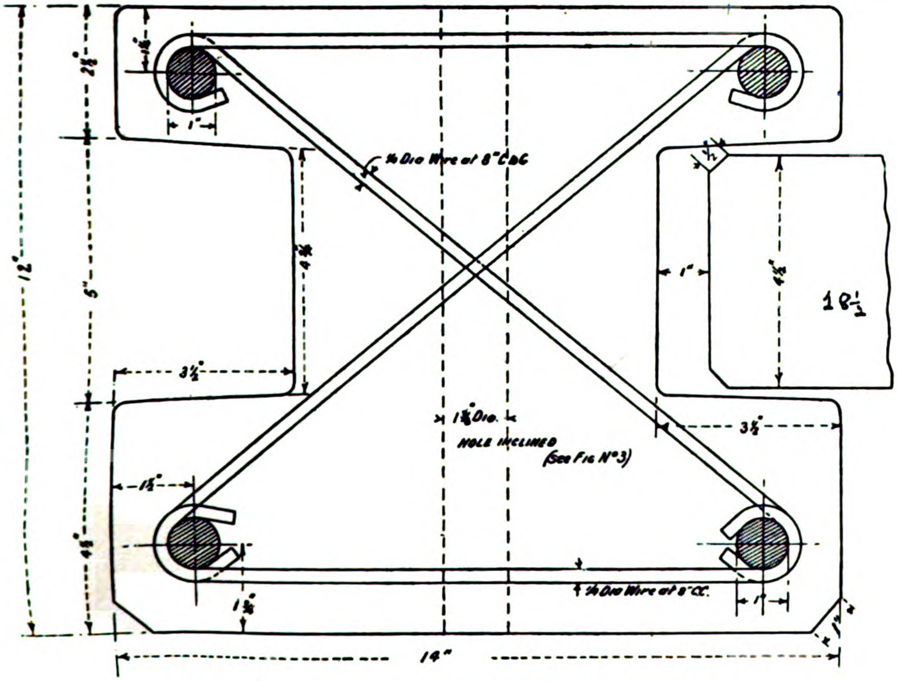


FIG. 2.—CROSS-SECTION OF MAIN PILES, SHOWING REINFORCEMENT.

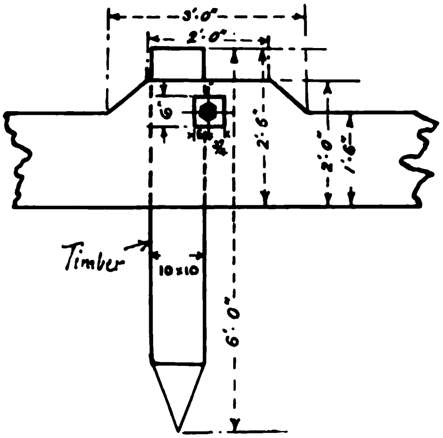


FIG. 3.—ELEVATION OF TIE-ROD ANCHORAGE.

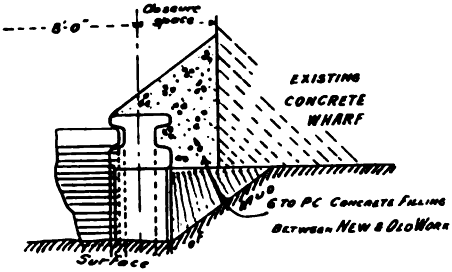


FIG. 4.—PLAN SHOWING METHOD OF JOINING NEW AND OLD WORK.

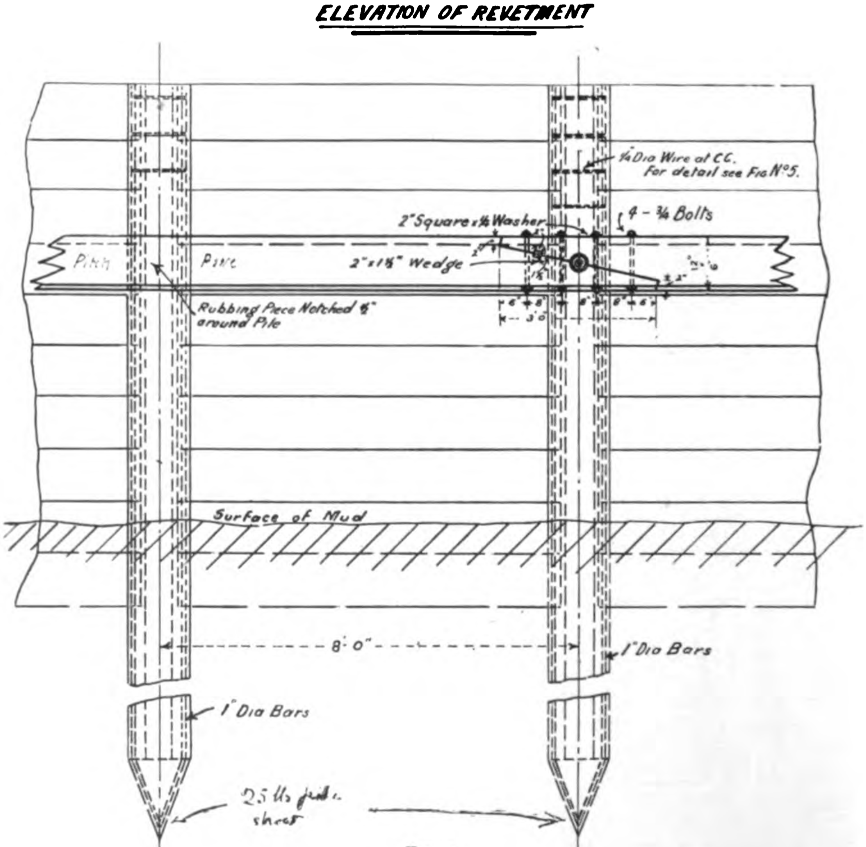


FIG. 5.

[*Mr. A. Havelock Case, M.Inst.C.E., Engineer.*

FLOOD PREVENTION WORKS ON BARKING CREEK.

entered into a contract with Messrs. Fairhead & Sons, of Enfield, to raise the level and revet the whole of their river frontage to a height of 18 ft. above Ordnance Datum, that is, 5 ft. 6 in. above Trinity High Water.

The premises, occupied by factory buildings and workyard, have a frontage of about 560 ft. on the Creek with an additional 506 ft. on a tidal tributary, the Loxford Water, making a total of about 1066 ft. of water frontage. On the Creek frontage the Messrs. Masters owned and used a small wharf about 60 ft. long which was considered quite sufficient for their needs; consequently wharfing the remainder of their frontage was considered to be an unnecessary expense, and a simple form of reinforced concrete revetment for the remaining 500 ft. of Creek frontage was adopted with a face batter of 1 in 8, whilst it was considered sufficient to protect the 506 ft. on the Loxford Water by a clay bank with stone-pitched face.

The reinforced concrete revetment was formed of grooved 12 in. by 14 in. piles, spaced 8 ft. distant centre to centre, and driven well into the gravel (*see Figs.* 2 and 5). The intervening spaces of each bay were closed by 12 in. by 4½ in. reinforced concrete slabs dropped loosely into the grooves (*see Figs.* 5 and 6), and the top finished off with a 12 in. by 6 in. reinforced concrete coping as shown in *Fig.* 7. The mud forming the bed of the Creek was excavated at low water for a minimum depth of 2 ft. prior to lowering the bottom slabs into position. The reinforced concrete slabs sliding loosely in the grooves of the piles permit of any future settlement and the making up at the cope line should scour or future dredging, or any other cause, induce such a condition.

As the soil forming the site is of a somewhat unstable character, each pile is tied back to a concrete anchorage dwarf wall by means of 1¼-in. diameter tie bars (*see Figs.* 3 and 6), whilst the

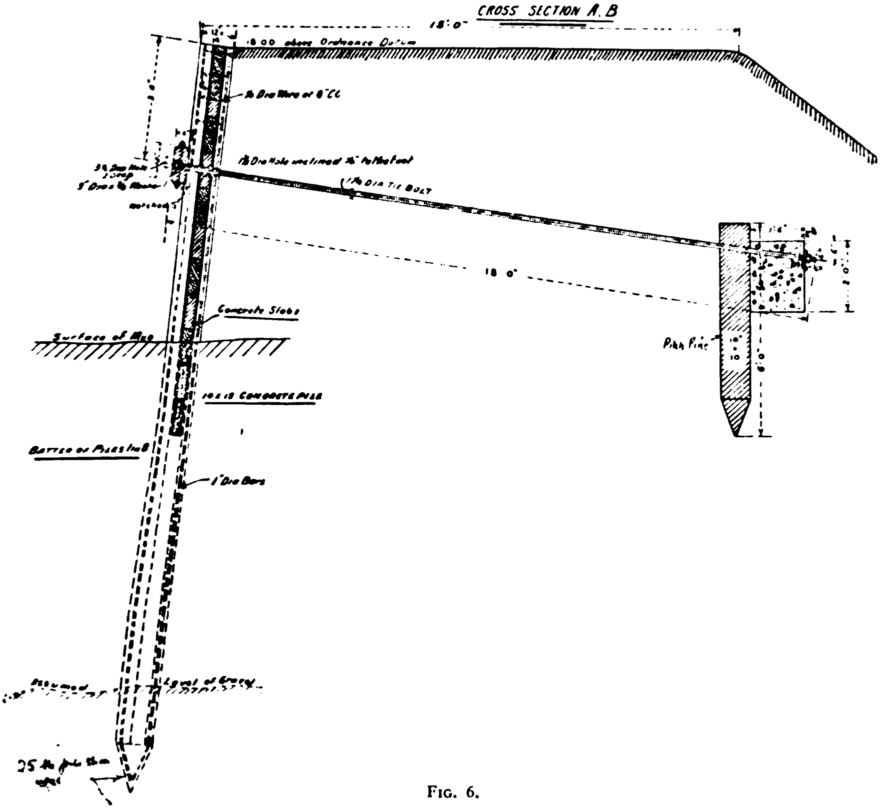


Fig. 6.

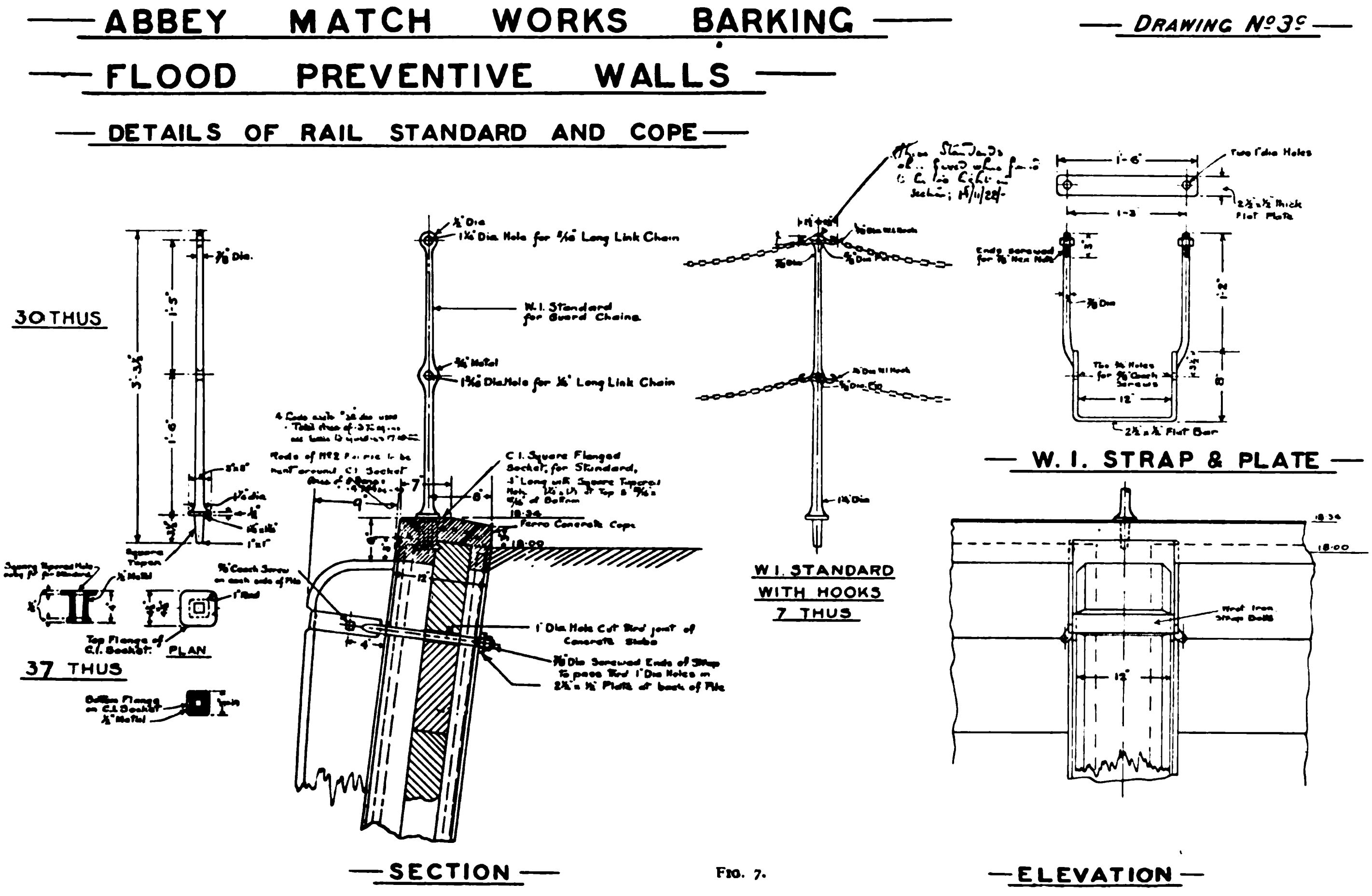

ABBEY MATCH WORKS BARKING
DRAWING No 3c
FLOOD PREVENTIVE WALLS
DETAILS OF RAIL STANDARD AND COPE
30 THUS
7/8" Dia.
1'-5"
3'-3½"
1'-6"
Square Tapen
½" Metal
Top Flange of C.I. Socket
PLAN
1" Rad
37 THUS
Bottom Flange on C.I. Socket ½" Metal
¾" Dia
1⅛" Dia. Hole for 5/16" Long Link Chain
W.I. Standard for Guard Chains
⅝" Metal
1⅛" Dia. Hole for ⅜" Long Link Chain
Rods of No 2 ... to be bent around C.I. Socket
C.I. Square Flanged Socket for Standard, 3" Long with Square Tapered Hole
18·34
Ferro Concrete Cope
18·00
⅝" Coach Screw on each side of Pile
1" Dia. Hole Cut thro' joint of Concrete Slabs
⅞" Dia. Screwed Ends of Strap to pass thro' 1" Dia. Holes in 2½" x ½" Plate at back of Pile
SECTION
W.I. STANDARD WITH HOOKS
7 THUS
1¼" Dia
1'-6"
1'-3"
Two 1" dia Holes
2½" x ½" Thick Flat Plate
Ends screwed for ⅞" Hex Nuts
⅞" Dia
1'-2"
Two ⅝" Holes for ⅝" Coach Screws
12"
2½" x ½" Flat Bar
W. I. STRAP & PLATE
Wrought Iron Strap Bolts
ELEVATION

FIG. 7.

whole of the work is tied longitudinally with a timber 12 in. by 6 in. waling notched over the main piles. The reason for using timber for this waling was that it might also serve as a rubbing piece for barges which might come alongside.

After the completion of the work it was found desirable to extend the old 60 ft. length of wharf, and for this purpose each main revetment pile over such extension was furnished with a vertical timber fender piece bolted to the face of the reinforced concrete piles and tapered from 9 in. at the top to 3 in. at the bottom, by this means the face batter of 1 in 8 was reduced for wharf purposes (*see Fig.* 7).

The total cost of the finished work, including subsequent extension of the wharf, was about £5790, which works out at approximately £2 10*s*. per foot run for the length of stone-pitched earthwork on the Loxford Water and about £8 per foot run for the reinforced concrete revetment faced frontage on the Creek.

As stated above the work was designed by Mr. A. Havelock Case, M.Inst.C.E., Wh.Sc., of the firm of Case & Cunningham, and the work was carried out by Messrs. Allen Fairhead & Sons, Contractors, Enfield, to whom we are indebted for the loan of photographs illustrating the work.

THE INSTITUTION OF STRUCTURAL ENGINEERS.

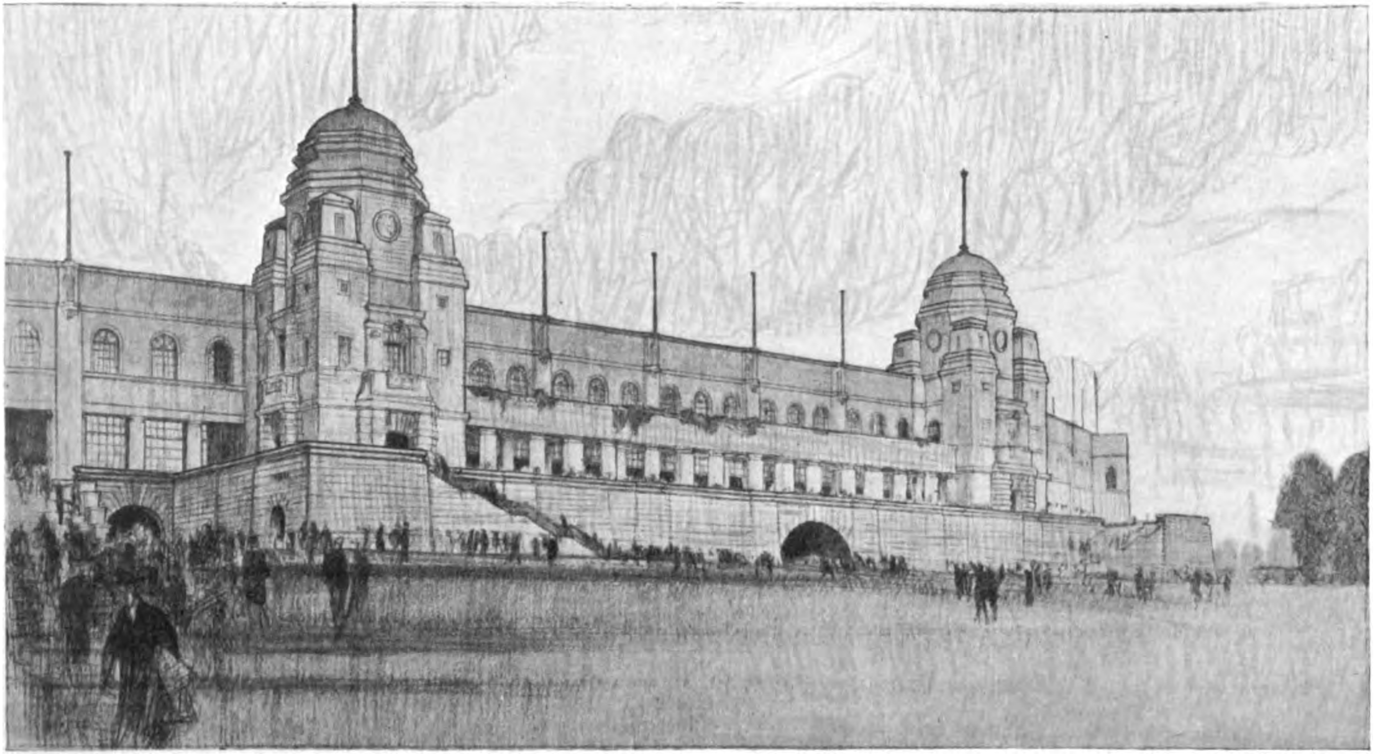
Some three hundred members and guests of the Institution of Structural Engineers were present at the annual dinner of the Institution held at the Criterion last month under the chairmanship of Major James Petrie, the President.

The after-dinner speakers included the President, the Rt. Hon. J. R. Clynes (Lord Privy Seal), the Rt. Hon. the Earl of Birkenhead, Sir Charles T. Ruthen, the Rev. F. H. Gillingham, and Mr. P. G. H. Fender.

In referring to industrial disputes, Mr. Clynes said strikes and lock-outs were a ceaseless source of trouble to all Governments. The Government could not force a doctrine of compulsory arbitration upon either employers or workers, for both would strongly object to such a course. The Government could only appeal for that measure of reason which would show how much better it would be to talk it out than to fight it out, and how much better it would be to reach a point of agreement mutually acceptable to both sides and enormously beneficial to the nation at large, before a blow had been struck or an hour of working time lost. The Government was anxious to inculcate such a spirit in industry; it was the British way as opposed to the Prussian way. Peace instead of force would be as beneficial in the industrial affairs of Britain as it would be a permanent blessing to mankind the world over if the doctrine of reason prevailed. The workers expected that unexpected lock-outs should not take place, and employers were also entitled to ask that lightning strikes and suddenly-sprung demands, or any other device used to achieve success regardless of reason, should cease.

Lord Birkenhead said the fact that men who had begun life in a difficult environment and had yet risen to the position of members of His Majesty's Government suggested some reflection. Were they so sure that there was anything wrong with the constitution of a country which gave opportunities for such distinguished talent to rise from such difficult beginnings?

The President said the Institution represented the structural engineering branch of civil engineering, which was at present carried out in concrete and steel, or a combination of the two. One of its principal objects was the advancement of the knowledge of structural engineering, and he thought most of them were striving in one way or other to attain that end; such an attainment must make for the general benefit of the community, for as newer, better, safer, cheaper, or more convenient methods of construction were found, so the public benefited by their application.



[Messrs. J. W. Simpson, PP.R.I.B.A., and Maxwell Ayrton, F.R.I.B.A., Architects.

MAIN ENTRANCE TO THE STADIUM: BRITISH EMPIRE EXHIBITION.

CONCRETE IN ARCHITECTURE.

MR. G. MAXWELL AYRTON, F.R.I.B.A., who with Mr. John W. Simpson, PP.R.I.B.A., is architect for the British Empire Exhibition at Wembley, gave an interesting lecture on the architectural possibilities of concrete last month at the Samson Clark building

The effort to keep in touch with the changing conditions and requirements of the times was, he said, perhaps more apparent in the world of design than in any other science, and the introduction of iron and steel was the greatest factor in the design of the last century. In the early part of the 19th century the introduction of cast-iron girders enabled spans and heavy loads to be negotiated with greater ease than had been possible formerly. From cast iron came rolled steel, which in its turn developed rapidly until reaching its present state.

In construction the change had been enormous. By leaps and bounds, wonder upon wonder of engineering had appeared. Architects had struggled with ever-increasing difficulties in their endeavour to keep up with those changes ; for steel construction required clothing, and the traditional materials for building purposes necessarily lost much of their meaning, as they became merely a facing to a sub-structure. One of the commonest instances was a great shop-front of a single sheet of plate glass with a horizontal lintel of stone hung up in its position to conceal the steel girder which was actually doing the work. Much ingenuity had been shown in dealing with those difficulties, but they could not be said to have been truly satisfactorily overcome. In most cases there was merely a compromise to the necessities of modern requirements.

During the past few years reinforced concrete construction had developed very rapidly, particularly in America, and there could be no doubt that it was the factor which must have the greatest influence upon the architecture of the future. It was a matter for surprise that it should so long have been regarded as purely an engineering expedient. That might perhaps be accounted for largely by the regrettable lack of partnership in design between architects and engineers. The closer union between those two great professions was one of the benefits which should transpire from the coming general use of reinforced concrete. The practice of working separately had unfortunately been too general.

The effect of a building upon its surroundings was as much an essential as the proper planning of its internal arrangement, and in dealing with reinforced concrete as an architectural material they were faced with one of the greatest difficulties that could be put to the would-be designer—that of departing from what the eye had become accustomed to.

Reinforced concrete not only opened up possibilities but demanded a treatment entirely its own, and at first it was a shock to find walls of incredible thinness, arches equally thin and apparently without the necessary abutments, staircases hanging in the air, and so forth. The enormous facilities of the material would undoubtedly be a danger to its development in design. There were always exuberant spirits who were anxious to dash at any new developments with the vain hope that they might produce something entirely new and their own, and they were bound to suffer during the next few years from this, to the detriment, for the time being, of the material. Only gradually, and in its own proper time, would it find its own, and forms inconceivable at the present time would presently be as satisfying to the eye as they would at the moment appear incongruous and fantastic.

As a material used by engineers surface treatment had not been considered seriously, and in consequence the question of shuttering had been treated merely from the point of view of getting the shape required in the finished article without regard to the appearance to the eye when the shuttering was taken down. And it was largely in the surface treatment of reinforced concrete that the architect would find his opportunity.

Shuttering was made by a particular type of joiner and carpenter—a man who worked quickly in a more or less rough and ready fashion, accurate to a degree in some respects but casual in others. The great objection to concrete buildings in the past had been that when the boarding was taken down the impression of the boards remained, leaving the roughness of the timber, the knots and grains and joints faithfully reproduced on the face of the concrete, so that the finished article appeared to be a rough timber construction of a very poor and temporary character. Various methods had been tried to overcome that difficulty—sand-blasting, hammering, chiselling, and so forth; but none of them was very satisfactory as they all entailed considerable extra labour and consequent cost in finishing off afterwards.

When it was decided to build the Stadium at Wembley in reinforced concrete that problem was one of the first to be tackled. It was realised at once that some surface finish was essential to such a building. The idea of roughcasting was discussed, and put aside as being too costly. Hammering and chiselling were also contemplated, but it was felt that was not dealing with the material in an honest fashion, for it was obvious that a material cast in a mould should not require further treatment after the mould was taken away; and, again, if the building were to be of concrete it should stand as such, upon its own merits. In discussing and considering the matter it was realised that the treatment of the surface should be obtained not by subsequent work upon the face of the cast concrete but by treatment of the internal face of the shuttering or moulds in which the concrete was to be cast. Fluted boarding was thought of and several lengths of walling were built, and by trial and error the sections of fluting or reeding which gave good results were eventually found. As the work proceeded the size of the fluting had gradually been increased, and the last work with the larger fluting was decidedly more satisfactory than the results obtained in the earlier stages.

In the forming of mouldings, projecting bands, recesses, flutings, etc., it must be constantly borne in mind that everything must be designed for the perfect flow of the material. The concrete was put in fairly wet, but had to be rammed down with rods between the steel reinforcement until every portion of the mould was filled. It was obvious, therefore, that the greatest care must be taken not to design forms into which the material must be forced against its will. The steel reinforcement formed a serious obstruction which could not be avoided and must not be added to unnecessarily; these matters could only be learned by experience and practice. Not only must the designer learn the lesson, but also the joiner or pattern maker, and the man who erected the shuttering and supervised its taking down.

As the use of reinforced concrete became more general practically a new trade would be created—that of the skilled maker and fixer of shuttering. The man who would know in an instant, when he saw an architect's drawings, exactly how he was to set about making his moulds and shuttering, and exactly what would and what would not make a good job, just as at the present time a first-class pattern maker for steel and iron was able to correct in a moment an error in judgment on the part of the designer.

The possibilities of reinforced concrete were immeasurable, and its advantages over others were many, among the greatest being speed. Again, it was conceivable that where the architect and engineer had sufficient time to complete the drawings for a building down to the last detail they might bring that to so fine a point that when the day came for the striking of the shuttering the building would be complete, and need no further finishing.

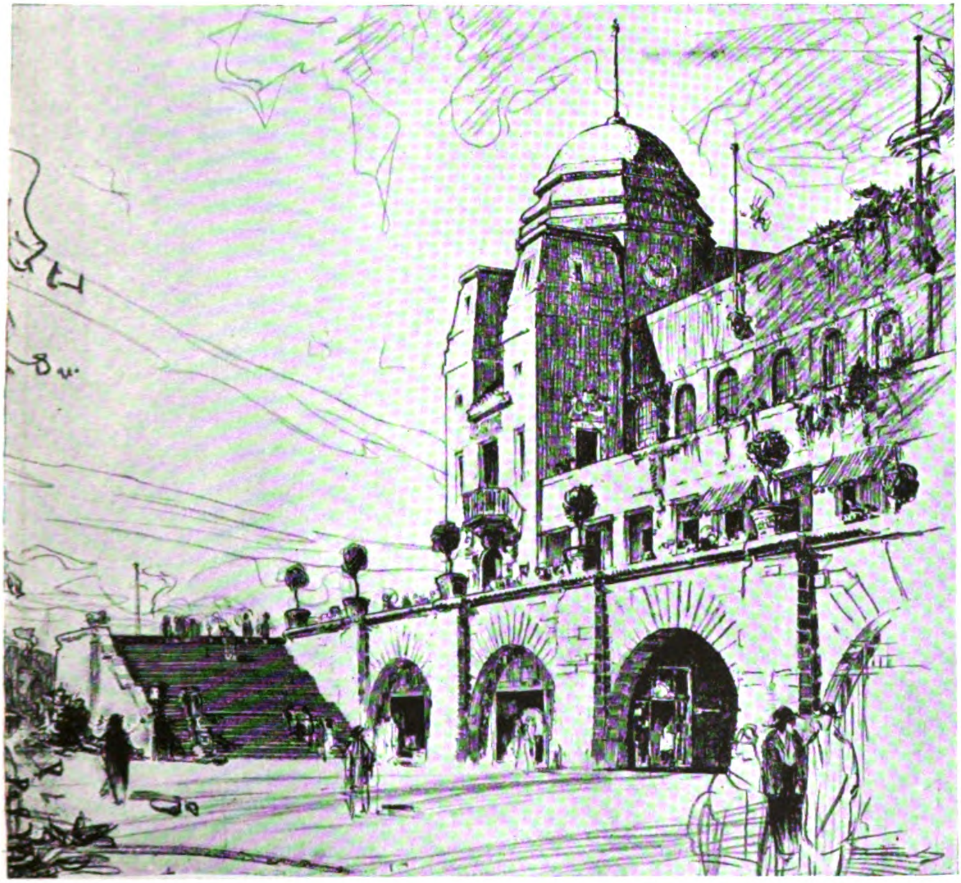
That was not the least of the charms of working in reinforced concrete. There was something extraordinarily satisfactory in arranging bolt holes, fixing pipe runs, etc., within the concrete as it proceeded, and so avoiding much of the work known in architects' specifications as "cutting away" and "making good."

To mention a few of the outstanding problems awaiting the architect, perhaps the most difficult was the satisfactory management of the expansion joints. Steel and cement expanded and contracted equally and together; otherwise, of course, reinforcement of concrete would be impossible, and that necessitated expansion joints at regular intervals. In some cases it was possible to cover the joint by an overlapping projection, but that was not always possible.

The composition of the concrete, and in particular the amount of water used, was of the greatest importance in the texture of the face. If too liquid the cement would run out to the surface of the shuttering, and when exposed would leave a "fatty" face, i.e. an unpleasant, almost polished, surface of pure cement, hiding the texture and colour of the aggregate entirely. The aggregate used was a matter settled by the local conditions, and might be pure gravel as at Wembley, or crushed gravel, granite, stone or broken brick. The coarse material and the colour of the sand used determined the colour of the finished work. The variety of colour at Wembley was astonishing and very beautiful—in the evening sunlight the Stadium had all the delicate shades of mother of pearl—on a wet day it took a cloak of grim black grey.

Another point to consider was the amount of concrete which could be placed each day, and that varied according to the thickness of concrete and the amount of reinforcement, etc. It was inevitable that a slight change of texture and colour happened at each lift, and it was desirable from every point of view that the lifts should be kept as horizontal and regular as possible. That was the reason for the adoption of the horizontal rusticated joints at Wembley.

Timber shuttering was bound to move slightly in filling, if only from the natural swelling of the timber when soaked with water. Therefore, some method should be forthcoming which would allow of this without detriment to the design; for instance, shuttering of a section like weather-boarding might meet some cases so that if it moved outwards slightly it would be unnoticed.



[*Messrs. J. W. Simpson, PP.R.I.B.A., and Maxwell Ayrton, F.R.I.B.A., Architects.*

EAST TOWER AND TERRACE OF THE STADIUM: BRITISH EMPIRE EXHIBITION, WEMBLEY.

CONCRETE ROADS IN HOT CLIMATES.

By R. A. B. SMITH, A.C.G.I., A.M.Inst.C.E.

With well-constructed concrete roads properly designed, transport maintenance is considerably lessened and the repairs necessary to the road are almost negligible, but there are several points in the design and construction of concrete roads peculiar to hot climates.

Assuming a sound foundation, the first question is the width of the road to be adopted. At first 14 ft. was considered sufficient, but so great became the increase of traffic when the advantages of the concrete road were realised that the Ministry of Health now recommends 20 ft., or multiples of 10 ft., i.e. 30 ft., 40 ft., etc.

In certain climates a uniform thickness of 6 in. for medium traffic and 8 in. for heavy traffic can be adopted as a safe standard, but in a hot climate other factors come into play and after spending large sums in experimental work it has been proved that when the temperature rises the surface of the concrete is heated first and therefore expansion tends to take place at a greater rate near the surface than below, causing the concrete slab to curl up at the sides, and on cooling at night or in cold weather the contraction tendency is again greater at the surface with the result that the concrete slabs tend to lift at the centre. Under these conditions it was found that lorries travelling with the near wheels about 2 ft. from the edge of the concrete would in time break the concrete at that distance from the edge. To meet this problem various designs were submitted to further heavy tests, and it was found that the best form of construction for such conditions was a concrete slab 9 in. thick at the edges tapering to 6 in. at a distance of 3 ft. from the edge, and this allowed the whole of the mid portion of the slabs to be reduced to 6 in. thick even for heavy traffic. Longitudinal bars ¾ in. in diameter should be provided along each edge of the concrete slabs, and a longitudinal joint is recommended along the centre.

In hot climates it appears inadvisable to have panels of a greater length than 30 ft., and for roads over 16 ft. wide a longitudinal joint down the centre appears necessary. If this is a plain butt joint abrasion is likely to occur in the course of time, when the joint opens, and to avoid this it is better to have a gap of ¼ in. wide filled with " plastos " or some filler of bitumen, sand and fibre. The transverse joints should be at least ¼ in. and filled with the same material. In each case the arrises should be tooled to ½ in. radius and the " filler " have been laid ¼ in. to ½ in. " proud " of the surface; this can be opened out and hammered into the gap. A slightly extra expense is incurred, but results justify the action. In this type of construction no reinforcement other than ¾-in. bars is necessary unless the foundation is bad.

It is essential that the stone or gravel and the sand should all be free of any foreign matter, such as sulphur, which would be injurious to the cement, and whatever is used must be clean. The stone should be graded from 1 in. to ⅛ in. and the sand should all pass through a ⅛-in. square opening and not more than 10 per cent. by weight should pass a sieve having 50 meshes per lin. in. If only a fine sand is available it will be found that a greater quantity of cement must be used to ensure every particle of sand being covered with cement. Unless this precaution is taken the concrete will fail. If the concrete is hand mixed it is recommended that the sand and cement be mixed dry before adding the dry coarse aggregate, and then the whole mixed wet.

The water should be clean, and in a country like India it should be analysed to ascertain whether anything is present likely to be injurious to cement, and if this is the case a very simple treatment will probably eradicate the evil.

The cement should be of the highest quality and slow setting. The difference between quick setting and quick hardening is not always fully realised; a slow-setting cement may be quick hardening, and if this is the case it is an advantage in road construction.

Generally speaking, the proportion of aggregate to cement should be 4 parts of coarse material to 2 parts of fine material to 1 part cement (1 : 2 : 4).

In towns it is sometimes preferred to make the road in two courses, the upper being richer to withstand the concentrated wear and tear, and in this case the top 1½ in. should be composed of 2 parts ½-in. to ¼-in. chippings or crushed ballast to 1 part sand to 1 part cement (1 : 1 : 2) or not weaker than 1 : 1½ : 3. Should this method be employed the top course must be laid almost at the same time as the lower course, and always before the initial set has taken place in the lower course.

In view of the fact that these roads allow of high speed it is advisable to bank the curves in proportion to their radius; the maximum super-elevation should occur through the centre half of the arc and should taper off for a distance along each straight equal to a quarter of the length of the arc.

In Great Britain these roads are often constructed in alternate bays about 20 ft. wide, the intermediate bays being filled in about 14 days afterwards when the initial contraction of the concrete of the adjoining bay has taken place, otherwise it appears advisable to have expansion joints at intervals as described above.

If the foundation will stand an 8-ton roller it is good enough, and all that is advisable is to blind it with a thin layer of sand or chippings to ensure the concrete being kept clean when deposited. If the foundation is liable to get spongy in wet weather and is then weak it should be properly drained by cutting diagonal trenches at intervals about 18 in. in width and depth and filling with gravel or some material which will allow the water to drain off and thus keep the top 18 in. fairly dry. If the foundation is liable to expand and contract a few inches of ashes rolled in will act as a cushion between the material and the concrete and thus prevent the latter from cracking. All banking must be thoroughly consolidated, and when the materials for filling are not all homogeneous they should each be deposited in thin layers and not promiscuously. The use of a 10-ton roller is advised on banks.

After grading the sub-base the forms should be set to the correct grade and made absolutely firm, as the tamper will work on them later. These forms should be at least 2 in. thick. It should be remembered that if these forms are not firmly butted it is probable that a ridge will show in the finished concrete surface. Before depositing the concrete the sub-base should be wetted in order that it may not absorb any moisture from the former.

The concrete should be mixed to such a consistency that if stamped on half a dozen times with a booted foot it just shows a moisture on the surface; the concrete is only weakened by making it wetter than this. About 5 ft. of concrete should be deposited and tamped, and the work followed up accordingly. As each 5 ft. or so is completed it should be immediately covered up with canvas, care being taken that the surface is not disturbed. The canvas should be kept damp, and may be in frames if desired. The canvas should be removed the next day and the concrete covered with sand and kept wet for 10 days.

The tamper for a road 18 ft. wide may be made out of 10-in. by 2-in., or 9-in. by 2-in. timber according to the amount of camber—if 9 in. by 2 in. is used a piece 2 in. square should be added at the top to prevent warping—this piece being laid on edge and nailed down.

The tamper should be provided with a shoe of wrought iron ⅛ in. thick and, say, 2½ in. wide, screwed in. The camber may be 1 in 48 and the tamper for a road 18 ft. wide would be 19 ft. long, the 6 in. at each end being level to act as a bearing on the forms. The handles should be close to the end.

Many engineers prefer the side forms to project an inch above the level of the finished surface at the edge of the road so that the concrete does not spew over the form, as this would make it necessary to continually clean it away from under the tamper where the latter bears on the forms.

BUILDING TRADES EXHIBITION.

The Building Trades Exhibition to be held at Olympia from April 11 to 26 promises to be as successful as any of those held within recent years. Among the exhibits of more particular interest to the concrete industry are the following:

Building Construction:—Kent Building Co., Ltd.—Stand No. 28, Row C—system of reinforced concrete walling on the pier-and-panel system; Siegwart Fireproof Floor Co., Ltd.—Stand No. 92, Row E—pre-cast concrete flooring system; Kleine Fire-Resisting Flooring Syndicate, Ltd.—Stand No. 116, Row F—concrete floors; Ruberoid Co., Ltd.—Stand No. 155, Row H—roofing materials; D. Anderson & Sons—Stand No. 118, Row F—roofing; Climbing Steel Shuttering Co.—Stand No. 318, Row S.

Cement.—Cement Marketing Co., Ltd.—Stand No. 117, Row F; C. A. Peters, Ltd.—Stand No. 69, Row D; Ironite Co., Ltd.—Stand No. 106, Row F; Lafarge Cement Co.—Stand No. 297, Row Q.

Machinery.—Triangular Construction Co., Ltd.—Stand No. 35, Row C—block-making machine; Drummond Bros., Ltd.—Stand No. 42, Row C—mixers; W. Kennedy—Stand No. 52, Row C—bar-bending machines; A. A. Byrd & Co.—Stand No. 239, Row N—metal shuttering; John Fowler & Co., Ltd.—Stand No. 241, Row N—mixers, placing plant, screens, elevators; Builders & Contractors Plant, Ltd.—Stand No. 250, Row N—mixers and hoists; Australia Concrete Machinery and Engineering Co., Ltd.—Stand No. 125, Row F—block-making machine, mixers, crushers, and barrows; Henry Banger—Stand No. 264, Row O—block-making machine; Liner Concrete Machinery Co.—Stand No. 283, Row P; Standard Concrete Machine Co.—Stand No. 316, Row S.

Reinforcement.—Johnson's Reinforced Concrete Engineering Co., Ltd.—Stand No. 146, Row G; Expanded Metal Co., Ltd.—Stand No. 151, Row G.

Asbestos-cement Products.—A. C. Rennie—Stand No. 72, Row D; British Fibrocement Works, Ltd.—Stand No. 144, Row G; G. R. Speaker & Co.—Stand No. 152, Row G; Turner Brothers Asbestos Co., Ltd.—Stand No. 160, Row H; Bell's Poilite and Everite Co., Ltd.—Stand No. 279, Row P.

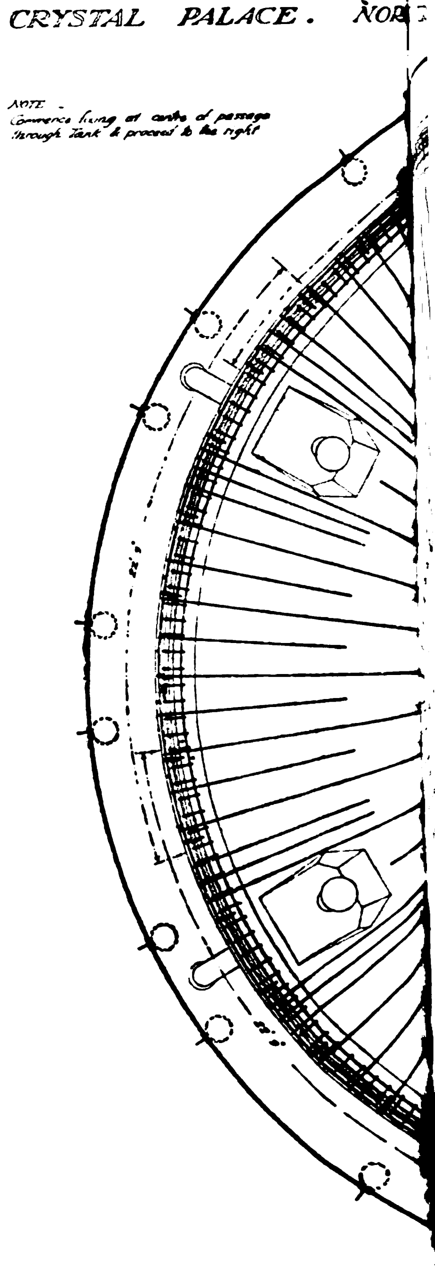
Concrete Products.—Croft Granite, Brick and Concrete Co., Ltd.—Stand No. 165, Row H.

Concrete Glazing Bars.—J. A. King & Co.—Stand No. 109, Row F.

Waterproofers.—Kerner-Greenwood & Co., Ltd.—Stand No. 49, Row C; Waterex Co., Ltd.—Stand No. 203, Row K.

The Concrete Utilities Bureau will, on Stand No. 115, Row F, give information on the uses of concrete, and distribute literature on the subject.

Copies of this journal, and our books on concrete, will be on sale on Stand No. 245A, Row N.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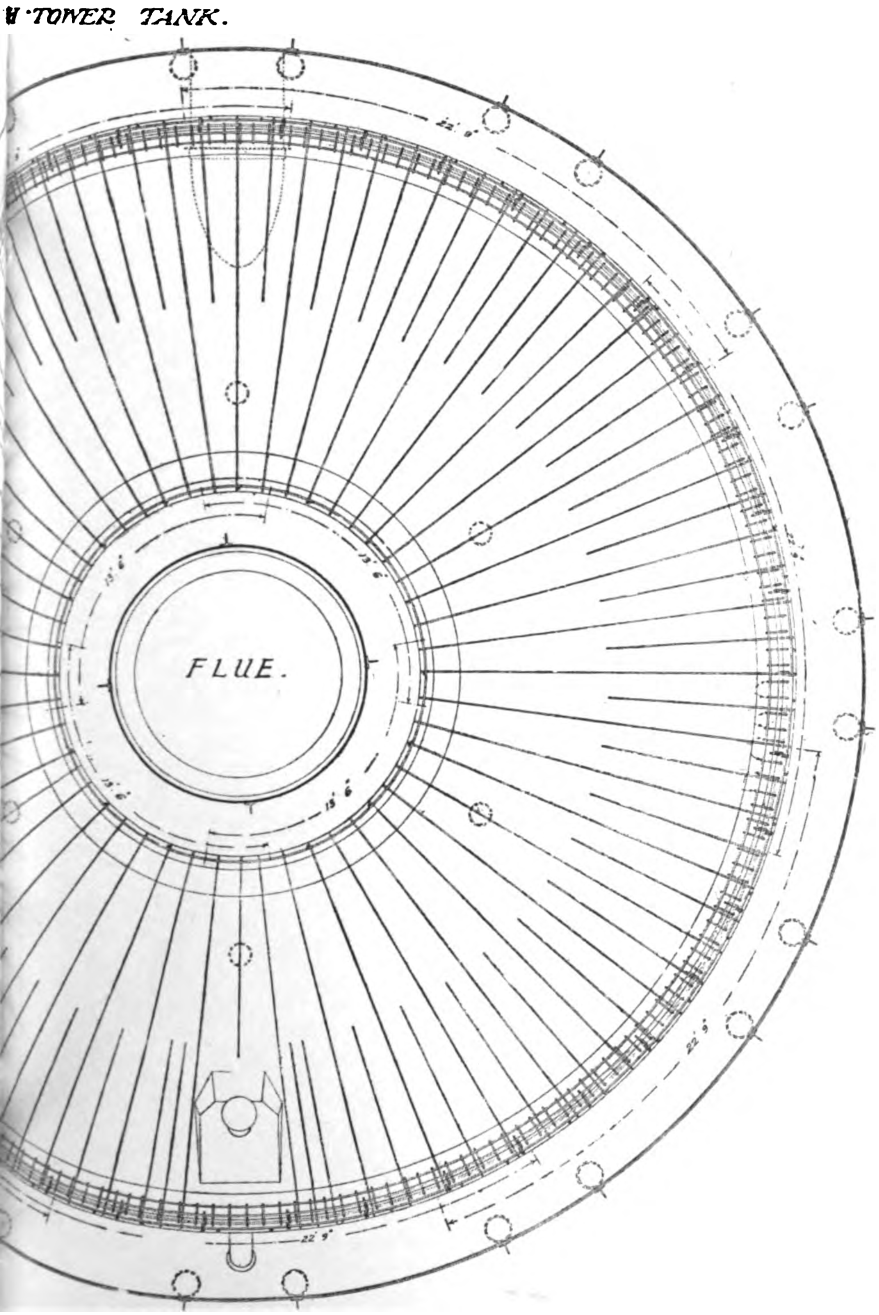
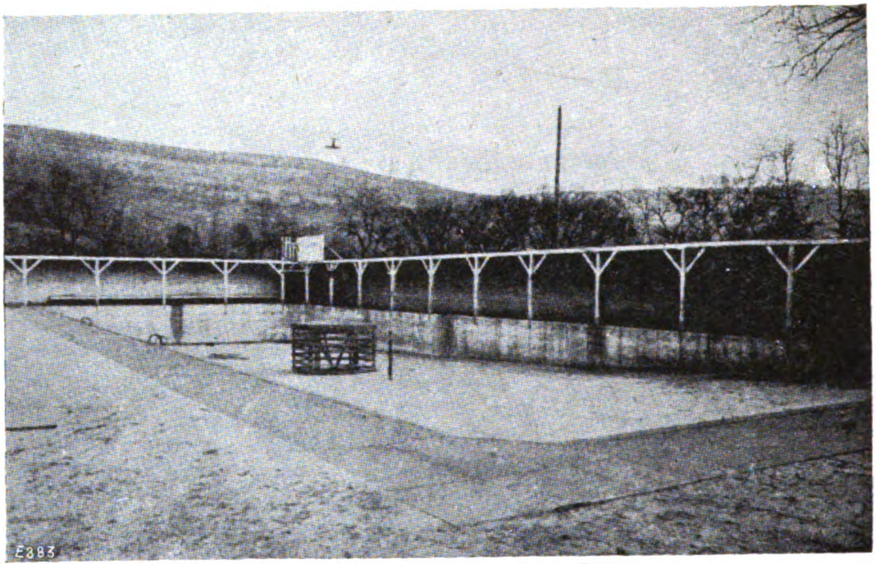
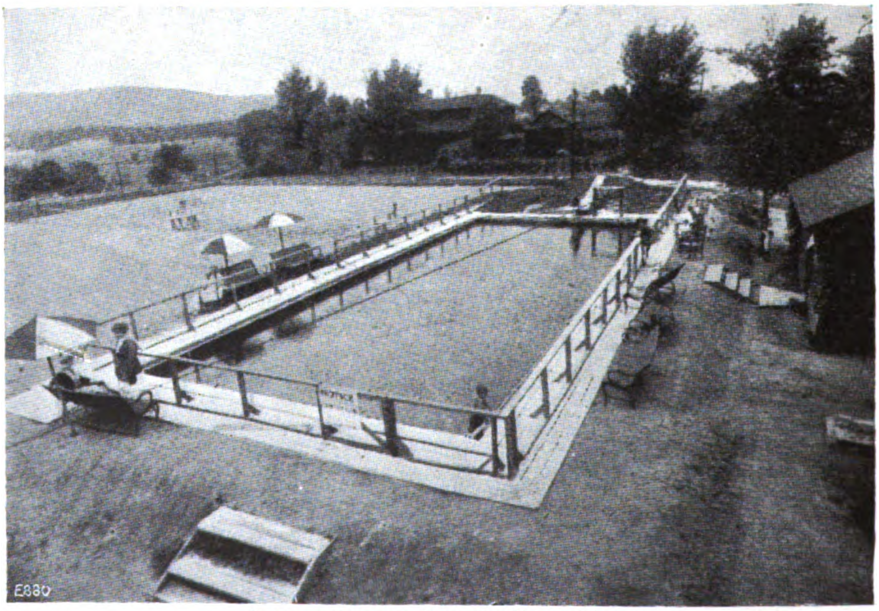
REINFORCED CONCRETE T



Detail of Reinforcement.
AT THE TOP OF THE NORTH TOWER AT THE CRYSTAL PALACE. *(See p. 219.)*



Concrete Swimming Pool in a Public Park.



Concrete Swimming Pool at a Country Club.

AMERICAN CONCRETE SWIMMING POOLS.

THE STRENGTH OF CONCRETE.

By **EWART S. ANDREWS, B.Sc., A.M.Inst.C.E.**

DUE to the careful and scientific methods that have been adopted by research workers who have tackled the important subject of the effects of the proportion of ingredients upon the strength of concrete, we are gradually arriving at the position at which it is possible with reasonable accuracy to forecast the strength of a given mix of concrete, and from a knowledge of the properties of the ingredients to choose the requisite mix to produce a concrete of given strength.

The work of Professor Duff Abrams during the past few years has shown the importance of the amount of water in the mix, and this point is confirmed and other points established in the work of Professors Talbot and Richart recently published in Bulletin No. 137 of the University of Illinois. The Bulletin comprises 116 pages, and sets out in detail the results of hundreds of tests on various fine and coarse aggregates, and explains a new method of attack which is an elaboration of the percentage-of-voids method; this method thus comes back into favour after some years in the wilderness.

THE "THIRTEEN POINTS" OF PRINCIPLE.

The authors give at the beginning of their thesis the following principles affecting the relation of the ingredients to the strength and density of the concrete.

(1) Definite quantitative relations exist between the magnitude of the voids in the concrete in place (water and air voids) and the compressive strength of the concrete, the quality and quantity of the cement and the quality and nature of the aggregate remaining the same, but the gradation of the aggregate varying, and other conditions remaining similar. The percentage of voids should therefore be taken as an index of the strength of the concrete in such cases.

(2) If concrete be made up with differing amounts of cement in such a way that the voids in the concrete remain the same, the nature of the aggregate and other conditions also remaining the same, the strength of the concrete will vary with the amount of cement used.

(3) For different amounts of cement and different gradations of the aggregate, the quality of the cement and the quality and nature of the aggregate and other conditions remaining the same, the strength of the concrete varies with the ratio of the amount of cement used in a unit of volume of concrete to the voids in this volume, and the strength may be taken to be a function of this cement-voids ratio. Instead, the ratio of the voids to the cement may be used. In some respects it is still better to consider the strength of the concrete as a function of the ratio by dividing the absolute volume of the cement by the sum of the voids in the concrete and the absolute volume of the cement—a ratio that may be termed the cement-space ratio.

(4) If the amount of mixing water be varied in such a way as to change the bulk of the concrete the strength will still be a function of the cement-voids ratio of the resulting concrete, though the function may differ from that which applies with the smaller water content. When there is much difference in the relative water contents, the value taken from a strength curve based on a minimum volume of concrete may be multiplied by a coefficient corresponding to the given relative water content.

(5) For the usual concrete mixtures—i.e. for those that make an easily worked concrete, including all mixtures used on construction—the bulk of the coarse aggregate is less than the bulk of the concrete; or, in other words, the bulk of the mortar in a given volume of concrete is greater than the voids in the coarse aggregates alone—the term mortar being used here to include the cement, fine aggregate, and water. For such mixtures the voids in the concrete may then be considered to be made up of the water and air-voids in the mortar. The density of the mortar for the consistency used in the concrete is therefore an important factor in determining the strength in the concrete.

(6) If the amount of the water and air-voids in the mix of mortar to be used in making the concrete are known (the term mortar here meaning the combina-

tion of cement, fine aggregate, and water which enters into the concrete), the voids in a resulting concrete may be calculated and the corresponding cement-voids or cement-space ratio may be used as an index of the strength of the concrete.

(7) By determining the voids in mortars made with a given fine aggregate, but with varying proportions of cement, a characteristic mortar-voids curve giving the relation between the voids in mortar and the ratio of fine aggregate to cement may be made up for any given fine aggregate, and information will then be available on which to base calculations for voids and strength of concrete made with definite proprtions of cement, fine aggregate, and water.

(8) By determining the voids in various mortar mixes made with different fine aggregates of the same character, and thus obtaining characteristic mortar-voids curves of the given fine aggregates, comparisons may be made of the relative densities and probable resulting strengths of concretes made up with these mortars and with assumed volumes of coarse aggregate.

(9) Knowing the characteristic mortar curve of a fine aggregate, the general nature and quality of the aggregate otherwise being known, the proportions of the mix required to give a specified strength (including the amount of cement, fine aggregate, and coarse aggregate) may be calculated with a fair degree of accuracy.

(10) The foregoing principles and methods are most readily applied by the use of the absolute volumes of the cement, fine aggregate, and coarse aggregate; but if the voids in the fine aggregate and the coarse aggregate in a dry state or in the condition obtaining on the work are known, or the relation between the weights by bulk and by solid volume, the bulk of the fine aggregate and the coarse aggregate required to make a unit of volume of concrete may readily be determined from the absolute volume given by the calculations already described.

(11) If the mixture is such that the voids in the aggregate are not fully filled by the mortar, the mortar voids will not be the measure of the voids in the concrete; but if the voids in the concrete and the ratio of the cement to the voids in the concrete are known, the ratio of the cement to the voids in the concrete may still be an indication of the strength of the concrete, except in the more extreme cases.

(12) The amount of voids in a specified mixture of mortar may be used to determine the acceptability of a given fine aggregate, so far as size and gradation are concerned.

(13) The method may be used to design the mixture of the concrete whatever the amount of cement used and whatever the ratio of coarse aggregate to fine aggregate, provided the mortar fill the voids in the coarse aggregate.

BASIC WATER CONTENT AND CHARACTERISTIC MORTAR-VOIDS CURVE.

Mortar tests are made of fine aggregate in which the voids are determined for increasing amounts if mixing water, and the amount of water which gives the minimum volume of mortar (least voids) is called the basic water content; then for this basic water content a curve is drawn, a curve representing the voids in the mortar for varying ratios of absolute volume of fine aggregate to absolute volume of cement. This curve is called the "characteristic mortar-voids curve." Such a curve for one sand is shown in *Fig.* 1, a corresponding curve for water content 1·40 times the basic content being also shown on the same diagram. This curve clearly shows the increase in voids when more than the basic content is employed.

For the mixtures commonly used the water content ranges from about 1·10 to 1·40 times the basic value, although even wetter mixtures are to be found.

In finding the basic water content for a given mix of mortar, a curve is first drawn in which voids in mortar are plotted against water content per unit volume of mortar; *Fig.* 2 shows such a curve for four different sands, the mix in each case being 1 absolute volume of cement to 2 absolute volumes of sand. (The absolute volumes are obtained from the weights by dividing by the specific gravity multiplied by 62·4.) It will be noticed that each of these curves has a fairly clearly-defined bottom point; the water content corresponding to this is the basic water content.

Fig. 3 shows the characteristic mortar voids curve for the same sands, as shown in *Fig.* 2. These curves refer to basic water content in each case corresponding to the lower curve of *Fig.* 1.

It is quite clear from this that the mix to give minimum voids at basic water content varies with the quality of the sand—the coarse sand being better than the fine in respect of the voids.

CEMENT-SPACE RATIO CURVES.

Professors Talbot and Richart take as a determining factor in the strength of the concrete the quantity which they call the cement-space ratio. This is obtained by dividing the absolute volume of the cement (c) in a unit volume of freshly-placed concrete by the sum of the voids in a unit volume of concrete (v) and the absolute volume of the cement, *i.e.* cement-space ratio $= \frac{c}{v + c}$. When the compressive strength is plotted against the cement-space ratio, the water content being basic in each case, a smooth curve results, as shown in *Fig.* 4.

This figure shows the results of a large number of tests, and the results are remarkably uniform considering the variations which are usually found with concrete test results. The authors prefer this form of curve to one in which the compressive strengths are plotted against the voids-cement ratio $\left(\frac{v}{c}\right)$, although the latter curve is somewhat easier to plot.

REDUCTION CURVE FOR WATER CONTENT.

From a study of the results of a large number of experiments the authors have devised the curve shown in *Fig.* 5 for enabling the compressive strength of concrete to be forecasted for a given water content when the compressive strength of concrete of the same mix with basic water content is known. It will be seen that the strength of concrete is reduced by about one-third of its basic value when the water content is 40 per cent. above the basic value; the curve can also be employed for finding the probable compressive strength of basic water content when the compressive

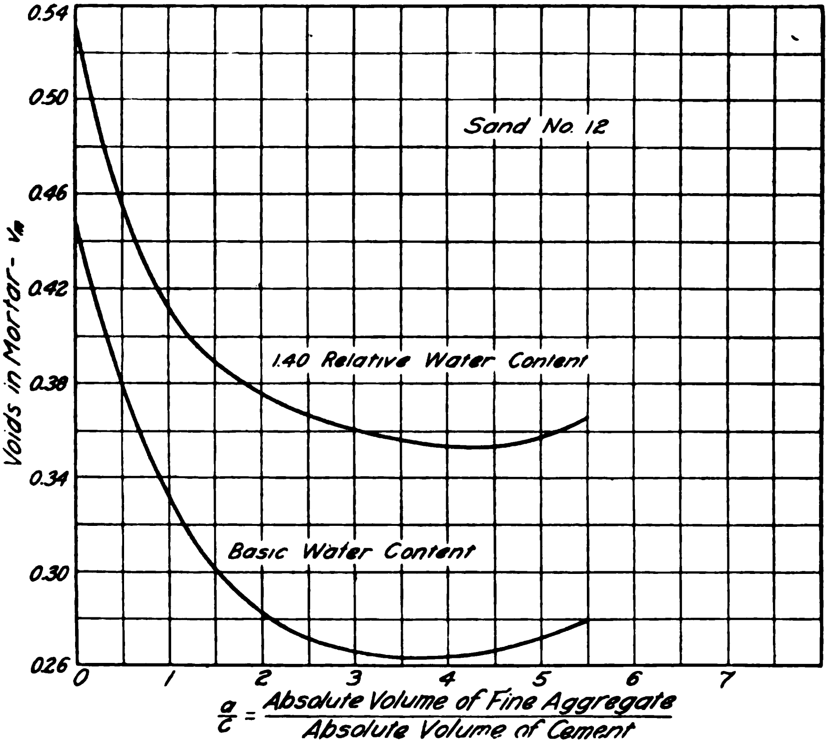


Fig. 1.—Characteristic Mortar-Voids Curves for One Sand.

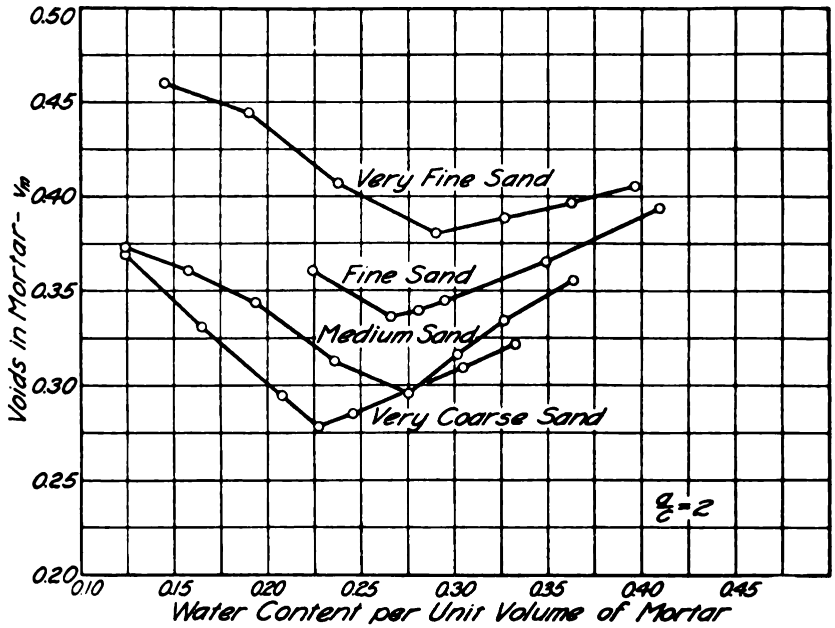


FIG. 2.—VARIATION IN VOIDS IN MORTAR OF GIVEN MIX WITH VARYING WATER CONTENT.

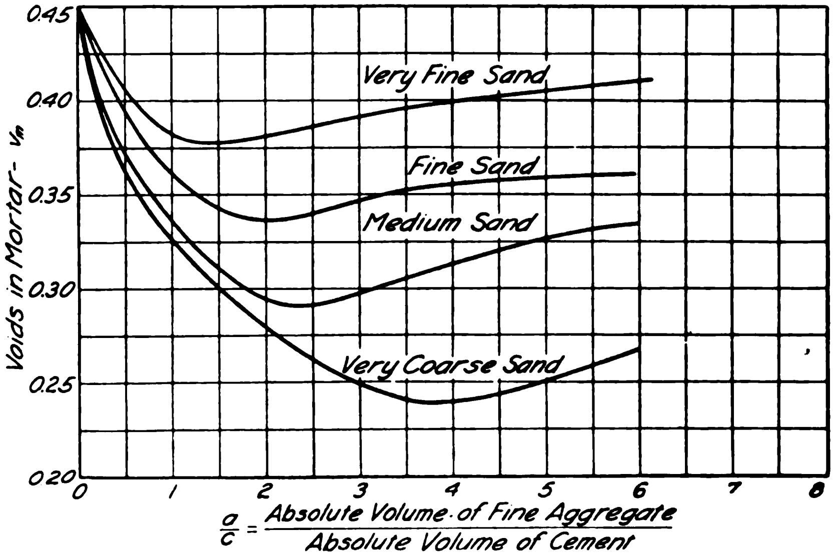


FIG. 3.—CHARACTERISTIC MORTAR-VOIDS CURVES AT BASIC WATER CONTENT.

strength at a given water content is known.

By the aid of this reduction curve the authors modified the results of tests with blocks of varying water content, and from these modified results plotted the diagram shown in *Fig.* 6. It will be seen that this diagram bears a close resemblance to that shown in *Fig.* 4, and thus shows that the reduction curve can safely be employed to forecast the results for other water contents.

WORKABILITY OF CONCRETE.

An important property of a concrete mixture lies in the ease of placing or pouring. It is important that the concrete fill every part of the form and come in complete contact with the reinforcing bars. It is also of advantage to have the concrete homogeneous throughout; that is, to have the large and small particles uniformly distributed through the mass, and to have freedom from pockets, or even very small spaces not occupied by mortar. It is desirable that this condition be obtained with little effort and expense. This property of the concrete is now known as "workability" or "mobility." The means of measuring the degree of workability of concrete so far devised are not fully satisfactory. The slump test is at best applicable to comparisons with the same gradations of materials and the same richness of mixture; for comparisons with widely different materials and richness it is crude. The flow table is a better instrument generally for comparative purposes, since the jar produced by the drop tends to overcome the viscosity of the mixture; it does not, however, take into account all conditions that enter into the workability of concrete. In considering the workability of concrete it is well to keep in mind that the cement, fine aggregate, coarse aggregate, and water—in amount or nature—each has a bearing on the workability of the mixture.

At the drier mixtures, a mixture rich in cement has sufficient viscosity to give low workability to the concrete. With the addition of water beyond the basic water content the effect of the presence of the larger amount of cement is to increase the workability.

A fine sand acts somewhat as does the cement. With a fine sand the voids in the mortar are not filled until a high relative water content is reached, and a noticeable effect of the increase in mixing water upon mobility is not found until considerable water has been added. With a coarse sand this condition is not apparent.

Water aids in lubrication—an increase in the mixing water beyond the point where the air voids become relatively

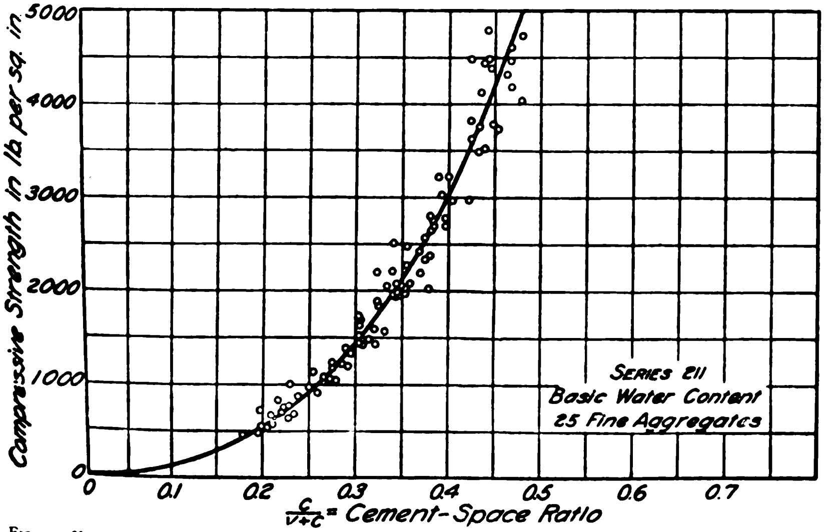


FIG. 4.—VARIATION OF COMPRESSIVE STRENGTH OF CONCRETE WITH BASIC WATER CONTENT FOR VARIATION IN CEMENT SPACE RATIO.

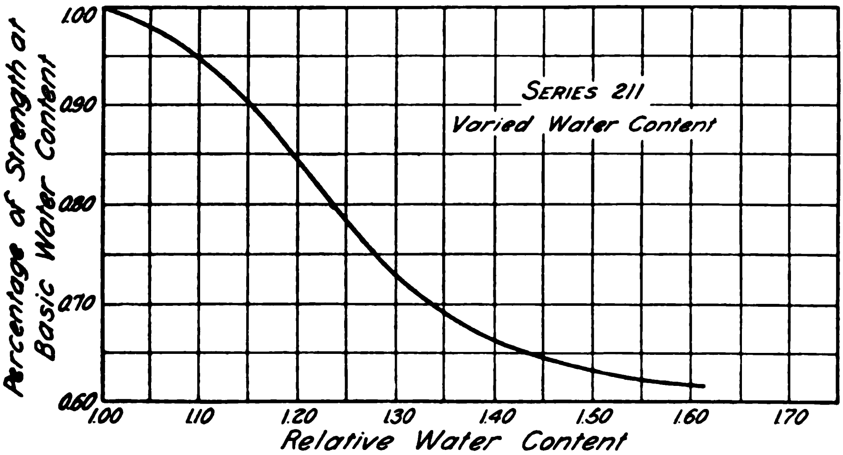


FIG. 5.—REDUCTION CURVE FOR CONCRETE OF VARIED WATER CONTENT.

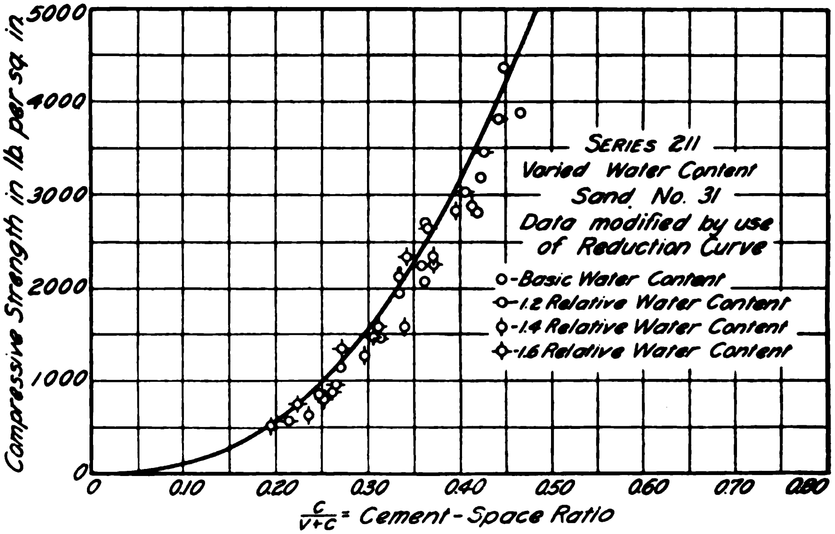


FIG. 6.—VARIATION OF COMPRESSIVE STRENGTH WITH CEMENT-SPACE RATIO OF VARYING WATER CONTENTS, MODIFIED BY REDUCTION CURVE OF FIG. 5.

small increases the workability, but a point is finally reached where the addition of water has little effect.

The shape of the particles of the coarse aggregate affects the mobility of the mixture, especially in a coarse mixture. Round particles make a most easily worked concrete. As may be expected, broken stone with rough surfaces and marked angularity gives difficulty in placing, especially when its amount is close to the upper limit of what may be put into concrete. A very well-graded coarse aggregate is less easily worked than one of more nearly uniform size, at and near the upper limit of *b*. When the amount of coarse aggregate used is decreased to values well below the upper limit the workability of the concrete is improved, and it is possible by such a change to effect a decreased relative water content and yet secure increased mobility with no loss in strength.

The usual method of trying to secure increased workability is to increase the amount of the mixing water. This method is fairly effective through a certain range, say perhaps from a relative water content of 1·10 to 1·50, the limits depending upon the richness of the mixture, the nature of the fine aggregate, and the coarse aggregate and other matters. Beyond this range the excess of water has little effect on workability and tends to produce segregation in the mass, and the water will not remain uniformly distributed throughout the concrete.

In using added water to improve workability it should always be kept in mind that the presence of additional water beyond what is termed the basic water content results in decreased strength in the concrete. In many cases the addition of 50 per cent. of water to the amount which will give what is ordinarily termed normal consistency will produce a concrete having only about one-half the strength of that at basic water content. In many cases it will be possible to obtain the requisite mobility in other ways, such as a decrease in the value of *b*, and to maintain much of the strength lost through adding water. Frequently, excess water is used through lack of knowledge of the great loss of strength resulting.

The above short account of the work of Professors Talbot and Richart will give an idea of the fact that a scientific thoroughness has been combined with an appreciation of practical conditions, and it is believed that much benefit will result to the concrete industry by a careful study and application of the principles laid down in this valuable contribution to the literature of the subject.

CORRESPONDENCE.

AGGREGATE FOR REINFORCED CONCRETE STRONG ROOMS.

SIR,—I should be greatly obliged if you would kindly let me know through the medium of your columns what is considered to be the best aggregate for the walls of a reinforced concrete strong-room. The particular work I have in view is a small treasury or strong-room for a bank, measuring approximately 30 ft. by 20 ft. on plan and 8 ft. ceiling height, the walls, floor, and roof being approximately 2 ft. 6 in. thick. I have had discussions with several different contractors as to the merits of aggregates, such as granite and whin, in resisting attack by fire, oxy-acetylene flame, cold drill, etc., but as the opinions expressed have been so varied I should be very glad to hear what you or any of your readers may have to say on the matter.

"ENQUIRER."

RAPID CONCRETE CONSTRUCTION.

In our February issue we gave some illustrations of the No. 1 Dominion Government Grain Elevator at Vancouver, B.C., an example of particularly rapid reinforced concrete construction, and we have now received some further particulars as to the methods by which this speed was obtained.

Early in 1923 the Dominion Government decided that the growth of the grain business through the Port of Vancouver warranted an immediate extension of grain handling facilities, and in conformity with the policy then instituted of consolidating the operation of government-owned elevators and piers at Vancouver in the hands of the Vancouver Harbour Commissioners, it was decided to extend the capacity of the No. 1 Elevator from 1,250,000 bushels to approximately 2,000,000 bushels.

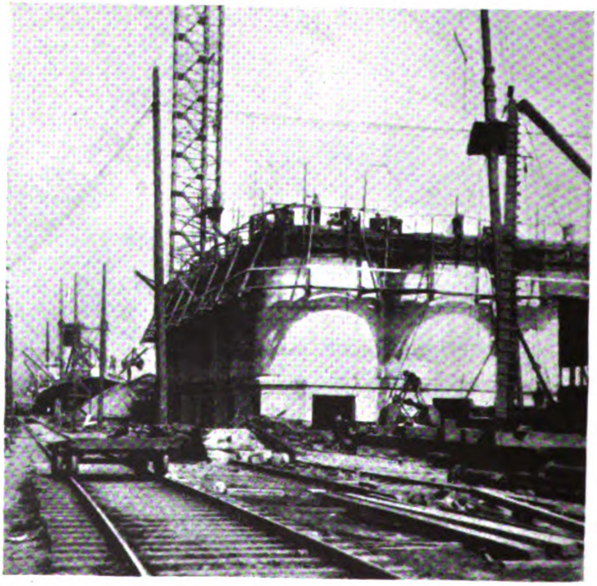
No. 1 Elevator was built by the Dominion Government Public Works Department in 1914, and for some years was idle, handling only local business. The rapid development of the export of grain had by 1921 taxed the capacity of this elevator and by the beginning of the current year more business was offered than could be handled. It was therefore decided to build the " No. 1 Annexe " as rapidly as possible.

Rapid work was evidenced not only in the construction but in the design as well. Complete plans were prepared for the entire plant in less than a month by the John S. Metcalf Company, in response to the Harbour Commissioners' urgent instructions to have the house available for this season's crop. The land on which the elevator addition stands was reclaimed from the harbour and it was necessary to run the foundation cylinders down a distance of 35 to 40 ft. to bedrock.

The addition is built of reinforced concrete throughout, and has a storage capacity of 850,000 bushels, served by a concrete shipping house containing four 15,000 bushel shipping legs.

The method adopted in building this elevator addition so rapidly was as follows. Instead of fixed forms built around the concrete, the moving-form system was used.

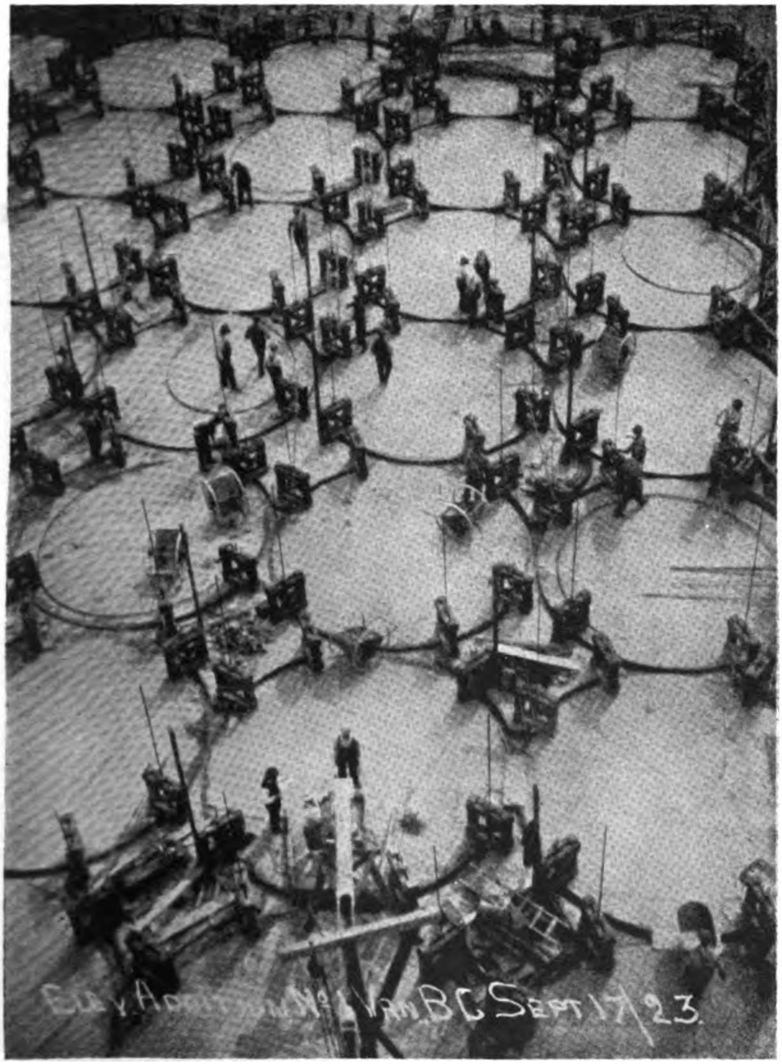
The wooden form was built 4 ft. high and assembled on the foundation for the bins and the workhouse. Heavy steel rods, of which 112 were used on this job,



Reinforced Concrete Grain Elevator at Vancouver: During Construction (September 11, 1923).

were placed upright, and to these the wooden form was attached with screw jacks. By uniform turning of the jacks the entire form was raised on the steel rods as the concrete was poured and set. One gang of men poured concrete, another gang tamped it down, the third gang placed the reinforced steel in place, while a fourth operated the jacks. By continuous working of shifts an average speed of nearly 6 ft. vertically in twenty-four hours was attained. As fast as the concrete was poured the form and the workmen on it were raised by the screw jacks, so that the soft concrete was never more than 3 or 4 in. from the top of the form. The form had to be kept moving or it would have adhered to the concrete. Working on a scaffold hanging over the form, a number of men smoothed over and finished the green concrete.

The result was that when the top of the



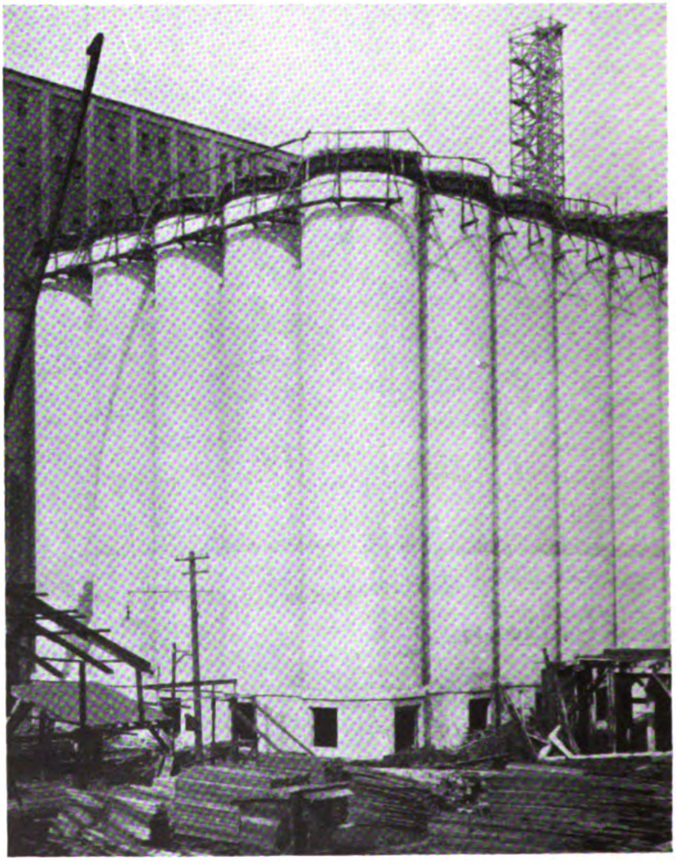
Reinforced Concrete Grain Elevator at Vancouver: During Construction (September 17, 1923).

bins was completed after sixteen days' work there was only the 4 ft. of wooden form at the top, the remaining 86 ft. of the column standing clean and white.

The whole of the concrete was poured in fifteen days. Pouring of the bin walls, which are 90 ft. high by 20 ft. in diameter, and contain 4,380 cu. ft. of concrete, was commenced by a night shift on September 6 last, and completed to the full height by noon on the 21st of the same month. Work on pouring the columns and beams of the working house was carried on simultaneously with the storage house, with moving forms working in conjunction with the circular bin forms. In this portion of the work 838 cu. yds. of concrete were used, and from the point where the pouring started the height is 148 ft.

Work on pouring the cupola, which extends beyond the top of the storage bins, was commenced in the afternoon of September 26 and completed on the morning of October 5.

The storage capacity of the bins is 850,000 bushels, made up of 35 circular bins of 21,000 bushels capacity each, and 28 interspace bins of approximately 5,000 bushels capacity each.



REINFORCED CONCRETE GRAIN ELEVATOR AT VANCOUVER: NEARING COMPLETION (September 24, 1923).

THE ACTION OF SEA WATER ON CONCRETE.

In the course of a report on "Concrete in Sea Water: Destructive Agents and Protective Treatments," a Committee of the American Concrete Institute states that as a preliminary to its investigations a questionnaire was sent to about seventy-five of the leading railroad, harbour, Government and municipal engineers who were most likely to have data on the subject. Of the fifty-one replies received, all but one gave approval to the use of concrete in fresh or sea water, and they were universal in stating that their general experience led them to believe that the failures of concrete in sea water service were attributable either to improper materials or poor workmanship.

The most emphasised essential of concrete for this service, continues the report, is impermeability, and, therefore, all methods of obtaining a mixture having this characteristic seem to have a place in any discussion pertaining to the subject. This, together with the best practices in the selection, proportioning, mixing, pouring, curing and protection of the exterior skin of concrete, must all be considered.

The exact chemical actions which occur when concrete is exposed to sea water are, as yet, only conjectures. One school, which is generally approved by most chemists, believes that it is the action of the sulphate of magnesia of the sea water with the lime in the cement (formed during the setting) and the alumina of the aluminates of the cement, resulting in the formation of hydrated magnesia and calcium sulphoaluminate which crystallises with a large number of molecules of water, and that both sodium chloride and magnesium chloride rapidly attack the silicates.

This action is due to the greater affinity of sulphur for calcium, so that when the cement and the sea water come together in the nascent state of chemical combination, the sulphur leaves the magnesium and combines with the calcium of the cement, forming calcium sulphate, and leaving the magnesium free. It is for this reason that the magnesium is frequently observed on the exterior of concrete structures which are subjected to the action of sea water. For a time chemists were of the opinion that the magnesia in the cement was in some way responsible for the deterioration. It is the feeling of the chemists of the Southern Pacific Co., who have made a very careful study of this, that magnesia in the normal amounts permitted in Portland cement is probably inert and does not cause the cement, in time, to expand and crack. In the transition of the sulphate of magnesia to the sulphate of lime, the two equivalents of water comprise a considerable increase of volume. This formation in itself is sufficient to destroy the cohesion, but the aluminate of lime which exists in cement in common with other calcareous salts possesses the property of combining with the sulphate of lime and thus forming sulpho-aluminate of lime. This combination carries with it such a large quantity of water that it is necessarily increased in volume, which, in turn, totally destroys the cohesion. Fortunately, the magnesium hydrate formed by the actions above described tends to counteract the destructive effect by filling the pores of the concrete, so that in this way the material may gradually become impervious to the sea water and disintegration is thereby prevented. After the character of the cement has been changed by the formation of the sulphate aluminate of lime, the sodium chloride in the water is able to dissolve the calcium silicate in the cement. The calcium set at liberty is dissolved little by little in the water, which penetrates the mortar and gradually reduces the concrete. The softening of concrete seems to take place only when there is an abnormal amount of sulphuric acid present.

Sea water has no apparent action on the iron oxides of cement. For that reason (and because of the fact that the setting quality of cement is due to the iron and alumina present, and, as indicated above, alumina is a harmful factor in sea water) it would seem that a cement high in iron is desirable. It is impossible, however, to replace all the alumina by iron, as a product resulting from the burning of ferric oxide and calcium carbonate does not possess hydraulic properties.

Continuing with the tests of this same railroad, it is of great interest to observe that the subjecting of pats of neat cement to water having slightly concentrated salts that are found in sea water showed

Pile No	Concrete.			w/c						Reported Condition.		These show little effect after 12 years.
					Water							
							Total					
	Mix	Consistency	Wt per cu. ft.	Cement cu. ft.	In Sand, lb.	Add. lb.	lb.	cu. ft.	Ratio w/c	Water in Core Hole in 1909.	1920.	
1	1 1 2	Dry	152 1	10 70	48	248	296	4 74	0 44	38	Eroded and split	..
2	1 1 2	Plastic	151 1	11 33	48	295	343	5 49	0.48	65	Very Good	•
3	1 1 . 2	Very wet	145 0	11 27	48	425	473	7 56	0 67	0	Very good	•
4	1 2½ : 4½	Dry	145 8	5 74	61	165	226	3 62	0 63	60	Bad erosion	..
5	1 2½ : 4½	Plastic	150 3	5 55	61	195	256	4 10	0 74	52	Very good	..
6	1 2½ : 4½	Very wet	152 2	5 73	61	345	406	6 50	1 13	0	Fair	.
7	1 · 3 · 6	Dry	142 5	4 69	59	182	241	3 86	0 82	16	Gone $\frac{HW}{LW}$	.
8	1 3 · 6	Plastic	146 6	4 68	59	240	299	4 80	1 03	22	Bad	
9	1 : 3 : 6	Very wet	145 4	4 68	59	343	402	6 43	1 35	0	Poor	
10	1 : 1 : 2	Wet	142 1	12 05	48	305	353	5 65	0 47	0	Good	.
11	1 : 3 6	Wet	146 2	4 80	59	353	412	6 60	1 38	0	Bad	.
12	1 · 1 2	Wet	145 9	11 45	48	325	373	5 97	0 52	0	Good	
13	1 : 3 6	Wet	142 8	4 62	59	345	404	6 46	1 40	0	Bad	.
14	1 1 · 2	Wet	144 2	11 35	48	330	378	6 05	0 53	0	Very good	•
15	1 · 3 · 6	Wet	142 7	4 66	59	335	394	6 30	1 35	27	Good	..
16	1 1 2	Wet	149 6	11 35	48	315	363	5 81	0 51	0	Very good	•
17	1 3 6	Wet	145 9	4 67	59	293	352	5 63	1 20	0	Bad	.
18	1 1 : 2	Wet	145 6	11 45	48	330	378	6 05	0 53	0	Very good	•
19	1 · 3 . 6	Wet	143 3	4 65	59	370	429	6 86	1 48	0	Lost 1916–1920	..
20	1 : 3 : 6	Plastic	145 5	4 62	59	275	334	5 35	1.16	0	Bad	..
22	1/10 Hydrated Lime 1 : 3 : 6	Wet	146 7	4 17	59	325	384	6 15	1 47	0	Gone $\frac{HW}{LW}$	.
23	Sylvester 1 3 · 6	Wet	137 9	4 73	59	298	357	5 71	1 21	0	Very bad	..
24	5 per cent Clay 1 : 3 : 6	Wet	151 6	4 18	59	275	334	5 35	1 28	0	Poor	.

Fig. 1.—THE "ABERTHAW" TESTS ON CONCRETE PILES IN SEA WATER.

total disintegration within ninety days, all apparently due to the foregoing chemical action. This test was confirmed by submitting some of the same cement pats to the action of real sea water over a period of one year. On the other hand, sand briquettes of 1 : 3 mix, made for physical tests in the ordinary way, submerged in sea water, show an increasing strength during tests that continued over a year. This may spell a caution in the minds of engineers in the matter of not proportioning their mortars in too great a percentage of cement. The inert sand seems materially to aid the cement in its resistance to the previously-described chemical reactions.

There seems to be no disagreement among the engineers or chemists with respect to the permanency of concrete which is entirely submerged. It is that portion of the structure which is subjected to the alternate action of water and air in which the destructive action is most apparent. In reviewing the supposed chemical actions described, it is obvious that this crystallisation should take place where the alternate action of water and air prevails. In this respect, the chemical hypothesis seems to be substantiated in general practice.

From a discussion of the supposed chemical actions, it seems wise to turn to a practical definition of the problems which have been developed from the information gleaned through experience, the questionnaire, and the practical experiments that have been carried on on this particular subject. For convenience and to avoid confusion, the subject is considered under the following headings :

(1) Impermeability and density.
(2) Proportioning and mix.
(3) Quantity of water.
(4) Forms, spading and tamping.
(5) Curing.
(6) Proper location and percentage of steel.
(7) Avoidance of seepage or drainage action, especially during the period of setting.
(8) Avoid placing the concrete where it is subject to the alternate action of air and water during the period of setting.
(9) Fxterior protection of concrete.
(10) Cement.

The tests which they carried on at the Charlestown Navy Yard, Boston, Mass., by the Aberthaw Construction Co., are perhaps the most scientific tests of long duration pertaining to the action of sea water on concrete which have ever been brought to the attention of the engineering world. The specimens, which have been exposed for more than thirteen years, are now old enough to warrant fairly definite conclusions. The relative duration of life of the different samples, together with the knowledge of their mixture and different conditions, afford an illuminating chapter in the study of the problem.

In these tests twenty-four reinforced piles, 16 in. square by 16 ft. long, were cast in January, 1909, with a view of introducing as many variables as possible to throw light on the subject under discussion. The general facts are given in *Fig.* 1.

In June, 1922, specimens numbered 2, 3, 5, 6, 10, 12, 14, 15, 16, 17, 18, 20 and 24 were in fairly good condition, and specimens 2, 3, 14, 16 and 18 showed little or no effect after the severe exposure between high and low water for the period of the thirteen years. The outstanding lessons from these tests are :

(1) Aim for impermeability rather than density.
(2) Use a rich mix.
(3) Use a sufficient amount of water.
(4) Avoid admixture of other materials with the cement.

The opponents of the use of concrete construction in sea water have, at various times, used the Aberthaw tests as an argument against the durability of concrete in this service for the reason that a substantial percentage of the test piles did not withstand the test of time. Those who are familiar with the conditions and the object of the investigations are undoubtedly well aware that certain extreme combinations were used for the express purpose of having some of the samples show rapid deterioration so that relative information might be forthcoming. It will be observed by referring to *Fig.* 1 that in every instance where a rich mix was used with a sufficient amount of water good results were attained. (See specimens numbered 2, 3, 5, 6, 10, 12, 14, 16 and 18.)

The tests show that the impermeability of the concrete is largely affected by the water content; that dry concrete is exceedingly dangerous; and that an excess amount of water seems to reduce the resistance to salt water.

Strength is an essential characteristic of concrete, but far more important is the providing of a concrete which will protect the reinforcing and withstand the chemical actions caused by the penetration of water. It is the Committee's opinion that this feature of concrete construction is not at the present time having sufficient consideration, and for that reason it is being specially emphasised.

(1) IMPERMEABILITY AND DENSITY.

The term "impermeability" is used to mean the relative resistance of concrete to the penetration of water under low pressure. A definition of density does not seem to be necessary. It is important to differentiate between the two characteristics of concrete, since the tests shown on *Fig.* 1 clearly demonstrate this point. It will be observed that Specimen 1, although having greater density than either Specimens 2 or 3, and being of identically the same mix (except water content) entirely disintegrated—so much so that the jar of lifting it out and placing it on the pier caused it to split and fall into pieces—while Specimen 2 is only slightly pitted and Specimen 3 is in exceedingly good condition. It will be observed that Specimen 3 showed no water in the centre hole, while Specimen 2 has more than Specimen 1. It seems probable, in view of the greater permeability of No. 1 as against No. 2, that the water ran out as well as in, and therefore the height at the time of measurement is not an exact indication of the relative permeability of the material. The 2½ in. holes, extending down from the top of the piles, were above water during the period of low tide and submerged about 5 ft. of their length during the period of high tide.

This test may, to some degree, have been affected by the low percentage of reinforcing steel which was used in the piles, namely, two ⅝-in. square twisted bars at two corners. This means that the pile, having apparently been picked up from one end, was subject to high unit stresses, thereby probably causing a number of small cracks which may have had the effect on the permeability test.

Pursuing the analysis of the other tests, it will be seen that the same general principles hold, except in Specimens No. 4, 5 and 6, where the maximum density and maximum impermeability seem to coincide. The most durable specimen, namely, No. 5, having a reasonable water content but apparently being quite permeable, shows far the best resistance to the action of sea water. There seems to be a relationship of importance between the providing of a sufficient amount of water and the permeability of the concrete.

(2) PROPORTIONING AND MIX.

All concrete is predicated on good materials, but good materials alone do not ensure perfect results. The Committee draws attention to Professor Duff Abram's "Design of Concrete Mixtures"* as a valuable guide for the proportioning of the different materials. It is important that a sieve analysis of the character described be made, and that the materials be assembled from this information, as set forth in the treatise mentioned; it is a matter of importance to every engineer who desires to produce a concrete that will resist these various destructive agents to give careful study to this problem.

The proportioning of the material shown in Specimens 4, 5 and 6 of the Aberthaw Tests affords a good illustration of unscientific mix. A careful analysis of the aggregates based on the "Design of Concrete Mixtures" shows that the theoretical quantity of sand to provide a mixture of proper fineness modulus is in excess of 33 per cent. In other words, if the mix had been 1 : 1·89 : 4·5, greater strength would have been attained for approximately the same amount of cement; or conversely, one-quarter of the cement could have been left out to secure the same strength, viz., the mix might have been 0·76 : 4·5, or a 1 : 2½ : 5·6, which, in turn, is approximately the same as a 1 : 3 : 6 mix. Since, up to a certain richness, the resistance to sea water action is apparently a function of the percentage of cement in the mortar, it is important that the mortar be made of sufficient richness and so proportioned with the coarse aggregate that the amount is only slightly in excess of its voids. Generally recognised practice indicates that the best mortar mix is about one of cement to one-and-a-half of sand.

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* See *Concrete and Constructional Engineering*, April and May, 1923.

The standard mixer provides a means of thoroughly mixing materials. Tests indicate that a 10 per cent. increase in strength may be secured by mixing longer than three-quarters of a minute to one minute, but generally practice seems to indicate that a mix of all the materials for the maximum of a minute is ample to provide excellent concrete.

One of the members of the Committee carried on a series of elaborate tests on the mixing of cement in water prior to the introduction of the aggregates. It was found that by mixing the cement and water in a small mixer during the period of charging the large mixer with the coarse and fine aggregates, and then introducing the cement and water into the large mixer for one minute mixing, caused an increase of about 20 per cent. in the strength of the concrete. This practice has not been followed out for the reason that the experiments were not carried to a point that demonstrated that such favourable results would be obtained under all conditions. There is a principle involved in this, however, that may be well worthy of consideration, namely, the mixing of the cement in a manner that assures complete hydration.

(3) QUANTITY OF WATER.

In the interests of permanency of construction, strength is not the paramount consideration in the proportioning of concrete. It is therefore important to make sure that a sufficient quantity of water is used to provide impermeable concrete. A careful analysis of the proportioning will disclose that the best mix will require the least amount of water in order to make it workable, and this is perhaps one of the simple means of determining whether the mix is approaching its ideal relationship. This feature of concrete making is of so much importance that the Committee feels constrained to give it perhaps undue emphasis.

Attention is directed to Specimens 1 to 9, in which it was apparently intended to mix three different proportions in three degrees of wetness. The consistency factor seems to disclose that this was attained to a remarkably uniform degree.

There is no evidence of deterioration because of excess water except perhaps in Specimen 6, which is clearly overwatered and which did not show as great an exposure resistance as Specimen 5. On the other hand, there are other inconsistencies in the relationship of the two specimens that are a little difficult to explain, namely, the greater density of the No. 6 specimen and the fact that this specimen seems to be much more impervious. The tests clearly indicate that an exceedingly careful watching of the water is necessary, and that the mixture should be workable and have a consistency factor approximating unity.

(4) FORMS, SPADING AND TAMPING.

The importance of well supported and rigid forms, which keep the concrete from moving during the period of placing and setting, is so well recognised that it does not seem necessary to do more than mention this in passing. There is, however, an important function of the form which is frequently overlooked. This function is the providing of a smooth face which congregates the cement and the rich ingredients of the mixture to the surface, forming a coating. The smoother the form and the more the tamping and spading, the more effective this protective skin becomes. Not only does the tamping work the air out of the concrete, but it also brings to the surface the materials which seem to be best suited to increase the impermeability of the mass.

(5) CURING.

This process in the producing of good concrete is frequently overlooked. It is of so much importance that a direct defiance of the laws of curing may vitiate the results with all other conditions perfect. Fundamentally, concrete must have excess water available during the period that it is setting. This is usually largely supplied by the moisture in the air both during the time the concrete is curing in the forms and after the forms are removed. But better still is the provision of a covering of material which will hold water, keeping such material saturated during at least the first two or three days the concrete is setting. If this is not possible, frequently the introduction of steam or boiling water in the air which is doing the curing will provide enough moisture to supply the demands of the concrete. Under no conditions should hot, dry steam pipes be used or dry radiation from fires. An exceedingly serious failure occurred not long ago in constructing a large factory building during cold winter months. In the anxiety of the builders to avoid any chance of the concrete freezing, large salamanders were kept burning near the columns immediately after they were poured. Not long after the building was finished these columns cracked, and the outside surface on all columns so heated fell off from a depth of two to six inches, exposing the steel and showing the internal stresses set up by the excess dry heat at the crucial time of curing.

Frequently in a climate where the direct ray of the sun is exceedingly hot, and even in temperate climates during the summer time, severe damage is done to concrete by exposing it to the sun before this initial curing is effected. It is a well demonstrated fact that concrete which sets under water and is not at any time subjected to the action of air or excessive heat has not only greater life but also greater strength.

A confirmation of this principle is disclosed in a paper read before the American Society of Civil Engineers. Cubes were cut from various specimens of piles which had more or less disintegrated, and these were tested for compression strength. Two cubes were cut from each pile, one above the water line and one below the water line. Apart from Specimen No. 7, which was badly shattered and from which, consequently, it was difficult to secure good cubes, the average strength of the top concrete as against the bottom was 92 per cent. The results of the tests were so uniform, namely, 91 per cent., 92 per cent. and 93 per cent., that the rule seems well established.

It is of interest to note that the strengths of these concrete pieces after thirteen years' exposure, even in the poorer specimens, such as 11 and 7, ran as high as 3,400 lbs. to the sq. in. This again demonstrates that there is apparently little relationship between strength and permanency. A strength of 3,400 lbs. for 1 : 3 : 6 concrete is far above the average result. It will be observed that the admixture of materials other than cement seems to subtract very greatly not only from the life but from the strength of the specimens, since in the same mix, namely, 1 : 3 : 6, Specimens 22 and 23 show from 1,700 to 2,600 lbs. compression strength, and the stronger specimen, namely, No. 22, shows very much less life than the weaker specimen, No. 23.

It is furthermore important in the curing (and, in the event of pre-cast units, in the handling) that care be taken to preserve the skin or outer coating. Information at the present time available leads the Committee to believe that it is unwise to attempt to rub down the exterior of concrete after it is cast unless it is done before initial setting takes place, which, under most conditions, is impracticable. Serious errors of this character are evidenced in concrete fencing and concrete ornamental work, where the removal of the surface coating has reduced the impermeability of the concrete and therefore removed the protection against the oxidation of the steel, which, in this character of construction, necessarily must be near the surface.

(6) LOCATION AND PERCENTAGE OF STEEL.

Investigations of the failures of concrete in sea water indicate that a large percentage is due to the oxidation of the reinforcing steel. In many instances the steel is properly placed but the concrete is so permeable that the ordinary thickness of the concrete is insufficient to protect it against unusual damage, particularly when subjected to alternate damp and dry air conditions.

The recommendation of the Institution of Civil Engineers' report, based on information gathered from various harbour engineers covering an experience of forty years, is that steel embedded from 1½ in. to 2 in. in concrete is safe against disintegration between high and low water. It is in this area that maximum oxidation of steel seems to take place. Below low water a lesser protection is required. The Bureau of Standards states that "Metal reinforcement is not subject to corrosion if embedded to a depth of 2 in. or more from the surface of well-made concrete." It is important that no metal attachment or metal reinforcement in the pile be exposed in any part of the structure above low tide, since corrosion of any portion of the reinforcement will convey the action through the whole structure.

It seems to be the best practice to use not less than ¾ of 1 per cent. of steel in members which are subjected to the variations of temperature which occur between submersion and the direct action of the summer sun. In many pre-cast members, such as pre-cast piles, this reinforcement increases to as high as 4 per cent. in certain sections. The important consideration with respect to the percentage of steel lies in the stresses to which the pre-cast member will be subjected while it is being put into place. Under almost all conditions this reinforcement is more than ample to take care of the structural strength after the member is in its final position. It is obviously necessary to provide sufficient reinforcement so that no undue stresses will be placed on either the steel or the concrete at any time during the process of driving or placing the member ; otherwise, initial cracks and breaking of the surface coating will occur.

(7) AVOIDANCE OF SEEPAGE OR DRAINAGE ACTION.

Apparently there is no action so detrimental to a concrete structure as the passage of water and the various impurities carried thereby through concrete. This is a well-recognised principle in the care with which engineers now waterproof all walls or buttresses which may in any way be subjected to hydrostatic pressure. This is of a special importance where laitance or other impurities form an opening to let the water penetrate first. If possible, drains should be provided so that difference in water pressures may be avoided.

Great care should be taken in making breaks in the pouring or in the joints where laitance may be deposited. It is recommended that the work be so laid out that each section will be completely poured in one run, thereby bringing all the laitance or impurities to the surface where they can be worked off.

(8) EFFECT OF ALTERNATE ACTION OF AIR AND WATER DURING SETTING.

The foregoing statement of the chemical actions which apparently take place between sea water and cement in concrete leads us to believe that this action will be greatly increased if the material is subjected to the alternate action of sea water and air before the complete hydration of the cement takes place. As might be expected, the saturation and drying apparently bring on the crystallisation with its attendant swelling and disintegrating mechanical effect. Experience has taught that practically all concrete which is placed without regard to this rule has shown serious disintegration.

One authority has indicated that the use of heavy cotton sacking inside the forms to protect the green concrete from the washing action and, to a certain degree, the chemical action, of the water (in this case fresh water) has entirely obviated this difficulty. It is the Committee's opinion that this method of protection will not avail in salt water, although no experiments, so far as is known, justify this conclusion.

(9) EXTERIOR PROTECTION OF CONCRETE.

The limitation of concrete with respect to wear is so well known that it is obvious that if heavy ice floes, flotsam, or other abrasive action from boats or ships are to be encountered suitable protection should be placed on the exterior. These are usually cheaply provided in some type of wood and should consequently be placed as low in the water as possible so that maximum life may be attained. It is recommended that this protection be so designed that no watertight pockets are provided which will retain moisture when the tide falls. During the cold weather the freezing of these pockets has a disruptive effect both on the concrete and on the protection. Evidences of disintegration of this character are shown in some of the reports made on piles at Atlantic City where copper or galvanised sheet iron has been used as a protection or form for the placing of green concrete.

It is the practice of some engineers to coat with some character of oil product that portion of the structure which is subjected to alternate high and low tide action. This is ostensibly for the purpose of keeping the moisture from penetrating into the surface of the concrete. Wax tailings is a product usually employed for this service, and seems to have no deleterious effect. It is doubtful, however, whether there is any particular advantage in the use of these protections. It is observed that barnacles or sea growth usually form on concrete when oil is not used. Frequently (as in the test pieces discussed) the oil in the water has coated the exterior of the piles. Apparently this keeps off the barnacles, but in turn effects a coating in itself. None of these protections, however, is of much avail unless the concrete is of good character.

(10) CEMENT.

The finding of the Bureau of Standards with respect to the composition of cement best suited to sea water service indicates that high iron content and high or normal alumina content did not show marked difference in tensile strength where exposed to fresh or salt water for a period of two years. Other cements of various compositions show signs of disintegration after a few weeks. "All cement resisted disintegration in the sea water better in mortar mixtures than in the form of neat briquettes." The Southern Pacific engineers hold that a cement low in alumina and fairly high in iron is desirable. Their rule is that the percentage of iron content subtracted from the percentage of alumina content should be less than four.

In the Aberthaw Tests Specimen 15 is the only 1 : 3 : 6 mixture that has stood up well during the thirteen years of exposure, and the cement used in this specimen was low in alumina. It is to be observed, too, that the same weak mix in the iron ore, or no alumina, cement—that is, Specimen 17—gave a very unsatisfactory resistance to the action of sea water. The same statement holds true in the weak mix and slag cement. On the other hand, the rich mixtures in all these three combinations show excellent results.

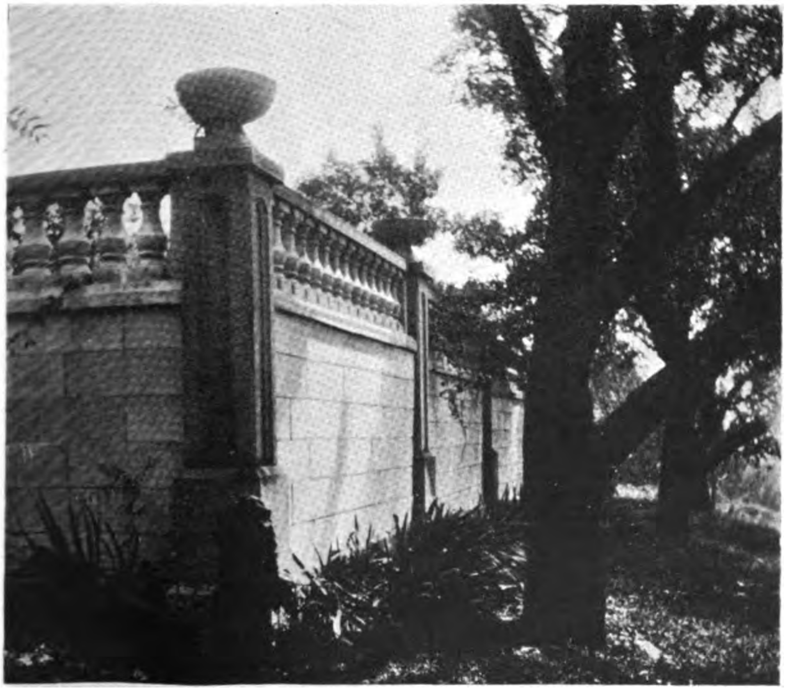
CONCRETE PRODUCTS.

In view of the increasing demand for pre-cast concrete goods, and of the size to which the concrete products industry has now grown, we propose in future to give more space in each issue to developments in the manufacture and uses of these articles. Descriptions and illustrations of new concrete products or new applications of concrete, for publication in this section, will be welcomed.

HOUSING SCHEMES CONTEMPLATED.

THE activity in small house building under the 1923 Housing Act still continues, and a large number of local authorities are considering schemes for the erection of working-class dwellings. Among the new schemes brought forward during the past few weeks are the following :—

Ashton-under-Lyne Town Council (50 houses).
Ashington Urban District Council (82 houses).
Askern Colliery Co. (350 houses).
Ballymena Urban District Council (100 houses).
Birkenhead Town Council (453 houses).
Brighton Corporation (123 houses).
Christchurch (28 houses).
Dundee Town Council.
Earsdon Urban District Council (336 houses).
Hastings Town Council (160 houses).
Edinburgh Corporation (1,000 houses).
Greenwich Borough Council (48 houses).
Ashington Colliery Co. (800 houses).
Norwich Town Council (1,000 houses).
Redcar Town Council (100 houses).
Rhymney Urban District Council (90 houses).
Stoke-on-Trent Corporation (500 houses).



CONCRETE WALL AND BALUSTRADE.

Rotherham Urban District Council (100 houses).

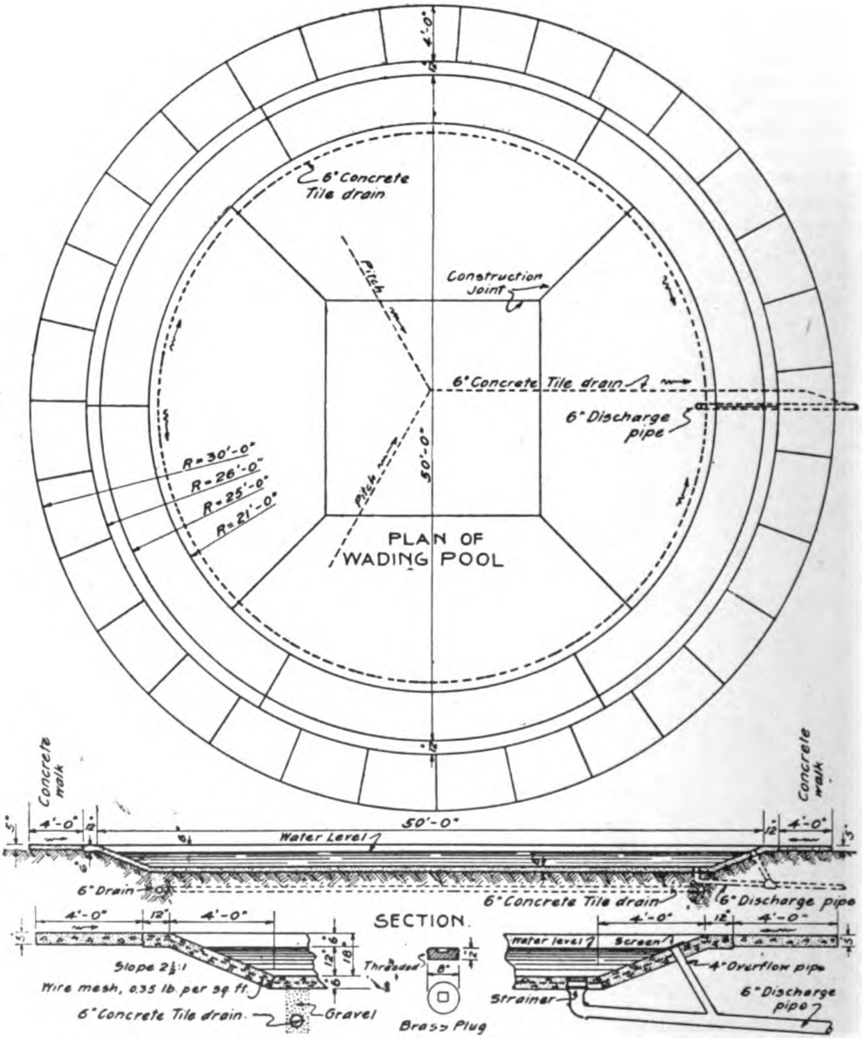
Wakefield Corporation (250 houses). .

Walthamstow Urban District Council (74 houses).

Worksop Urban District Council (100 houses).

Yeovil Town Council (100 houses).

Further particulars of these schemes are given in our list of " Prospective New Concrete Works," but we give prominence to these schemes in view of the opportunities they present of putting the case for the concrete cottage before the authorities concerned, and of supplying concrete products if it is decided to build the cottages of other materials.



Suggested Design for Concrete Wading Pool.

AMERICAN CONCRETE POLES.

A CORRESPONDENT in the United States writes :—

Hollow reinforced concrete poles are being extensively used in this country as well as in Europe.

The form shown in *Fig.* 1 is in three sections, two sides and a base. The core is made of galvanised iron, conical in shape, and is removed on the initial set of the concrete about four hours after it has been poured.

Fig. 2 shows how the pole is erected. The poles are put in 5 ft. deep and no concrete foundation is used. In *Fig.* 3 is shown an American hollow reinforced concrete pole erected on one of the prominent city corners five years ago.

The hollow concrete pole illustrated in *Fig.* 1 is 35 ft. in length, 7 in. at the top, and 16 in. at the butt ; it weighs 1,600 lbs. and will carry a strain of 1,500 lbs. side pull at the top when set 6 ft. into the ground. These poles are reinforced with deformed high-carbon steel rods, and can be made to carry any side pull by the introduction of additional steel in the butt of the pole. They can be handled

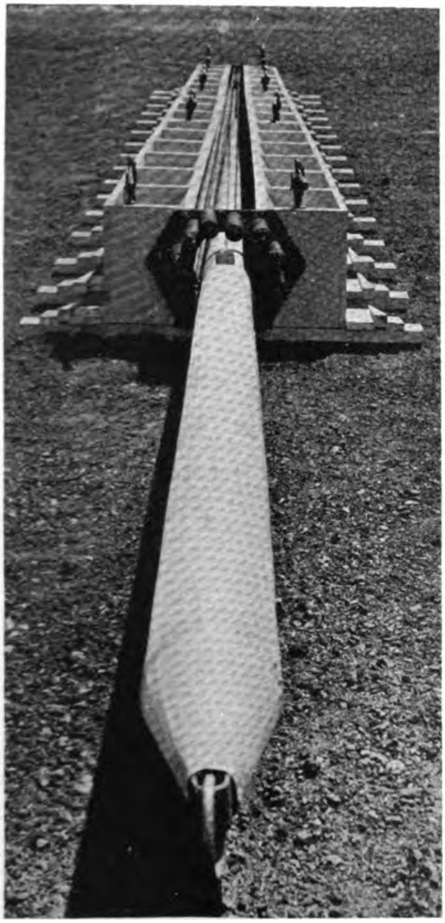


FIG. 1.—FORM AND CORE FOR 35-FT. HOLLOW REINFORCED CONCRETE POLE.

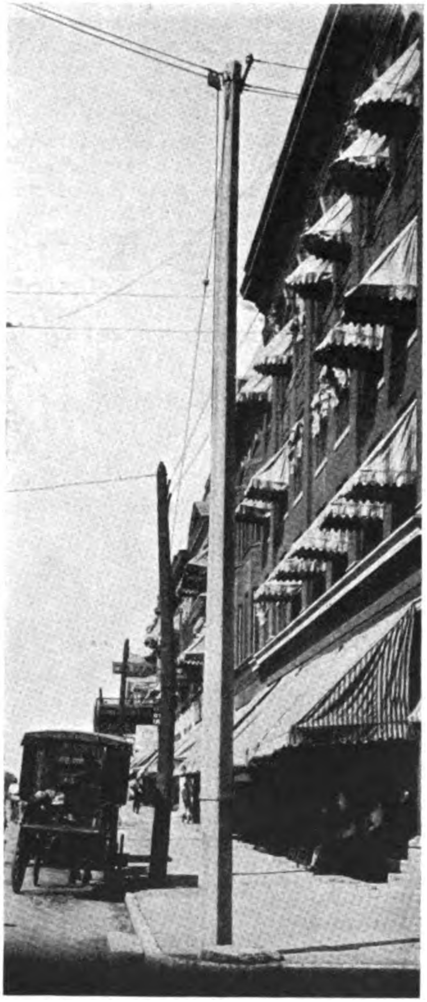


FIG. 3.—HOLLOW REINFORCED CONCRETE POLE AFTER FIVE YEARS' USE.

and set the same as ordinary poles. They are most easily set with a pole raiser, with which apparatus three men can set a pole. With the use of the moulds illustrated in *Fig.* 1 a pole can be made every 24 hours with one outfit. The poles can be made with or without steps, and they can be made any length by adding or taking off a section of the mould.

The materials required to make a pole 35 ft. in length, 7 in. at the top and 16 in. at the butt, are 12 cub. ft. of ½-in. coarse aggregate, 8 cub. ft. of sand, 3 cub. ft. of cement, and 430 ft. of ¼-in. deformed high-carbon steel for reinforcement.

It is claimed that one of the features of hollow reinforced concrete poles is the ease with which wires from overhead can be connected with underground systems, thus doing away with unsightly wiring from the tops of poles. Complete protection from lightning is also afforded by reason of the large amount of steel contained in the poles. Not only is there the depreciation of the pole, but the reconstruction of overhead wires on account of replacement of wooden poles soon runs into a large amount of money, all of which is avoided by the use of reinforced hollow concrete poles.

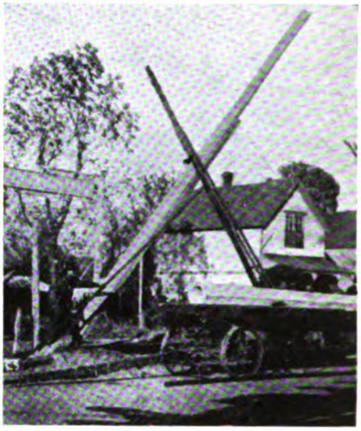


FIG. 2.—HOLLOW REINFORCED CONCRETE POLE BEING PLACED IN POSITION. THE POLES ARE SUNK 5 FT. IN THE GROUND AND NOT EMBEDDED IN CONCRETE.

The enormous development of transmission of electric power, and the extension of tramways, telephone, and telegraph lines, has produced a great demand for overhead electric cables and wires in all countries. The cost of such lines already forms a prominent part of

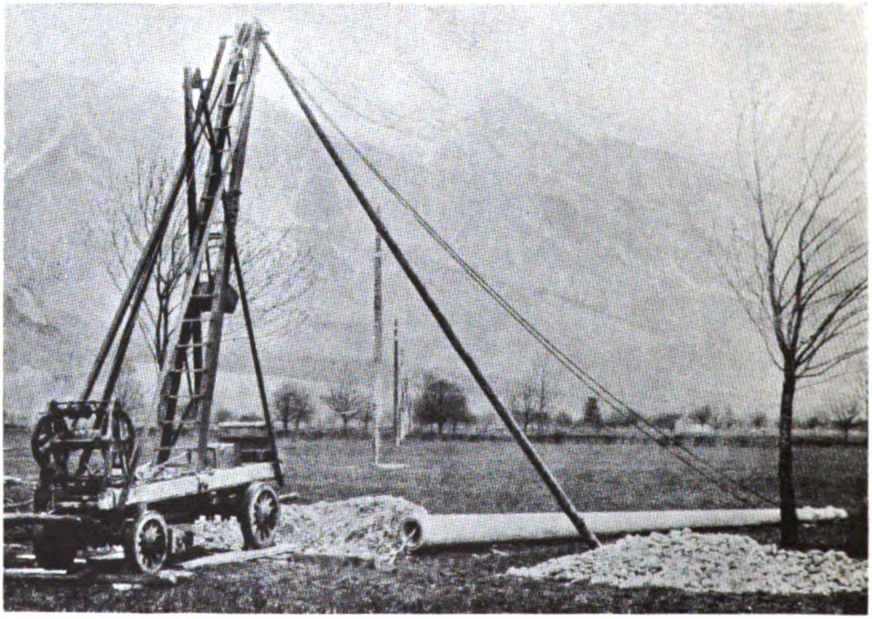


FIG. 4.—ERECTING A HOLLOW REINFORCED CONCRETE POLE.

the capital invested, and the poles for the support of the wires are to-day articles of considerable importance. The reliability of the lines is greatly dependent upon the security of the supports, and the general requirements for efficiency in this department include economy in first cost, adequate strength and reliability, as well as permanence and low cost of maintenance. All these conditions are assured by the use of hollow concrete poles. A recent return published by the International Bureau of Telegraph Administration records a total of 490,000 miles of telegraph lines in ten European states, and the great capital outlay for such lines makes it obvious that the reliability and cost of upkeep of the lines have become a matter of great importance.

CONCRETE COTTAGES.

In addition to the local authorities who have already decided to build concrete cottages under their housing schemes, we understand that the Wakefield Corporation proposes to erect 250 concrete houses within the next twelve months.

We also understand that the Wimborne (Dorset) Urban District Council has received an offer to erect 20 concrete houses on the Leigh Park Estate.

CONCRETE POSTS.

The Goole U.D.C. has accepted the tender of the Concrete Unit Co., Ltd., Manchester, for the supply of concrete posts.

CONCRETE SEWER TUBES.

The Birkenhead T.C. has accepted the tender of Messrs. J. Hogg & Son, Ltd., Belfast, for the construction of 182 yds. of 27-in. diameter reinforced concrete pipe sewer, and 421 yds. of 6 ft. 9 in. by 4 ft. 6 in. brick and reinforced concrete sewer.

CONCRETE PAVING FLAGS.

Among the recent tenders accepted for the supply of concrete paving flags are the following :—

Gainsborough.—The U.D.C. has accepted the tenders of Messrs. Brookes, Ltd., Halifax, and Messrs. J. F. Shackleton & Son, Goole, for the supply of concrete flags.

Hove.—The T.C. has accepted the tender of the Patent Victoria Stone Co., Ltd., London, E.C., for the supply of artificial stone paving slabs.

London (Chiswick).—The U.D.C. has accepted the tender of the Excelsior Patent Stone Co., Finedon Sidings, Northants, for the supply of artificial stone paving.

London (Lewisham).—The B.C. has accepted the tender of the Alexandra Paving Stone Co., Ltd., for the supply of artificial stone paving at 5*s*. 10½*d*. per yd. super.

Stratford-on-Avon.—The T.C. has accepted the tender of the Patent Victoria Stone Co., Ltd., Bishopsgate, E.C.2, for the supply of concrete slabs.

DATA FOR PRICING REINFORCED CONCRETE.[*]

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ½ in. mesh	,,	15	0
Best British Portland Cement	per ton 58s. to	63	0
"Ferrocrete" Portland Cement	10s. per ton extra		

Boarding for Shuttering—

		Sawn. s.	*Sawn.* d.	*Wrot.* s.	*Wrot.* d.
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £24 per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £25 ,, ,,

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
9/16 in. to ½ in. Rounds	,,	13	6
⅜ in. Rounds	,,	14	6
¼ in. Rounds	,,	15	6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed with Clean Water in proportion 1 : 2 : 4—

		s.	d.
Do. do. in foundation	per yard cube	45	6
Do. do. in columns	,, ,,	50	6
Do. do. in beams	,, ,,	50	6
Do. do. in floor slabs 4 in. thick	per yard super	5	4
Do. do. in floor slabs 6 in. thick	,, ,,	7	11
Do. do. in floor slabs 9 in. thick	,, ,,	11	6
Do. do. in walls 6 in. thick	,, ,,	8	2

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	24	0
,, 9/16 in. to ½ in.	,,	23	0
,, ⅝ in. to 2⅞ in.	,,	22	0

EXTRA LABOUR TO BENDS in ¼-in. rods, ½d.; ⅜-in. rods, 1d.; ½-in. rods, 1¼d.; ⅝-in. rods, 1½d.; ¾-in. rods, 1¾d.; ⅞-in. rods, 2d.; 1-in. rods, 2¼d.; 1⅛-in. rods, 3d.; 1¼-in. rods, 3½d.

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1d.; ⅜ in., 2d.; ½ in., 2½d.; ⅝ in., 3d.; ¾ in., 3½d.; ⅞ in., 4d.; 1 in., 4½d.; 1⅛ in., 6d.; 1¼ in., 7d.

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	55	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	51	0
Do. do. in small quantities	per ft. super	0	9½
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last, in narrow widths	,, ,,	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	,, ,,	1	1
Do. do. as last, in narrow widths	,, ,,	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are those current in the London area, namely:—Carpenters and joiners, 1/8 per hour; Labourers on building works, 1/3; Operators on concrete mixers and hoists, 1/4.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

PROSPECTIVE NEW CONCRETE WORK.

Ashington.—*Houses.*—The U.D.C. proposes to construct 82 houses.

Ashton - under - Lyne.—*Houses.*—The T.C. has applied to the M.H. for sanction to erect 50 houses.

Askern.—*Houses.*—The Askern Colliery Co. proposes to erect 350 houses.

Ayr.—*Waterworks.*—The T.C. proposes that the new main at Sillyhole Moss be supported on ferro-concrete piles.

Baddinsgill. — *Waterworks.* — The West Lothian C.C. proposes to construct a reservoir at Baddinsgill.

Ballymena. — *Houses.* — The U.D.C. proposes to erect 100 houses.

Baslow. — *Bridge.* — The Derbyshire C.C. proposes to construct a reinforced concrete bridge over the Derwent at Baslow, estimated to cost £24,000.

Birkenhead. — *Houses.* — The T.C. is considering a scheme for the construction of 453 houses, estimated to cost £300,966.

Boston.—*Bridge.*—The R.D.C. will proceed with the construction of a ferro-concrete bridge at Five House Lane, Wyberton.

Bournemouth. — *Bridges.* —The Corporation proposes to construct new concrete bridges in place of the wooden structures across the Boscombe Chine and Alum Chine Gardens.

Bridgend.—*Bridges.*—The U.D.C. has applied to the M.H. for sanction to borrow £1,000 in connection with the construction of bridges in the recreation ground.

Bridlington.—*Bathing Pool.*—The T.C. has applied to the M.H. for sanction to borrow £1,750 in connection with the proposed new bathing pool.

Brighton.—*Houses.*—The Corporation proposes to construct 123 houses at an estimated cost of £458 each.

Cardiff.—*Concrete Roads.*—The City Council proposes to form concrete roads in New Zealand Road, Canada Road, Australia Road, Fitzhamon Embankment, System Street, Moorland Road, and also part of Swansea Street.

Carmarthenshire.—*Reservoir.* — The Ammanford U.D.C. proposes to construct a storage reservoir, estimated to cost £8,000.

Christchurch.—*Houses.*—The T.C. has applied to the M.H. for sanction to borrow £10,000 for the erection of 28 houses.

Dundee.—*Houses.*—The Corporation Housing Committee has appointed a sub-committee to consider the erection of concrete houses.

Earsdon.—*Houses.*—The U.D.C. proposes to construct 336 houses on the Park House estate.

Failsworth.— *Bridge.* — The U.D.C. has applied to the M.T. for sanction to borrow £17,000 for the construction of a bridge.

Faversham.—*Road.*—A scheme for the construction of a coastal arterial road from Faversham to Thanet has been submitted to the M.T.

Gurnard.—*Road.*—The U.D.C. proposes to construct a shore road, estimated to cost £15,000.

Hollington.—*Houses.*—The Hastings T.C. is considering a scheme for the construction of 160 houses at Hollington.

Honiton.—*Bridge.*—The M.T. will make a grant of 65 per cent. towards the cost of the construction of a 30-ft. span reinforced concrete bridge over the River Yarty.

Linthwaite.—*Road.*—The Linthwaite D.C. proposes to construct a road from Huddersfield to Marsden.

Llangranog.—*Bridge.*—The Llandyssul R.D.C. has under consideration a proposal to construct a bridge over the River Hawen at Llangranog.

Lochend.—*Houses.*—The Edinburgh Corporation Housing Committee has recommended the Council to construct 1,000 houses at Lochend.

London (Charlton).—*Houses.*—The Greenwich B.C. proposes to erect 48 houses on the Charlton estate.

Lowestoft.—*Sea Defence Works.*—The T.C. proposes to construct a sea defence wall.

Lynmouth.—*Houses.*—The Ashington Colliery Co. propose to construct 800 houses during the next two years.

Mainrudge. — *Bridge.* — The Boston R.D.C. proposes to construct a ferro-concrete bridge 102 ft. in length in place of the existing footbridge.

Newcastle-on-Tyne. — *Bridge.* — The Corporation has a scheme on hand for the construction of a bridge across the Tyne between Newcastle and Gateshead, estimated to cost £1,000,000.

NORTON.—*Road.*—The Swansea Corporation proposes to construct a road off Boarspit Lane, Norton.

NORWICH. — *Bridge.* — White Friars Bridge, Norwich, is to be replaced by a reinforced concrete bridge, estimated to cost £16,000.

NORWICH.—*Houses.*—The Corporation has a scheme on hand for the construction of 1,000 houses, estimated to cost £500,000.

OSWESTRY. — *Sewage Works.* — The U.D.C. has applied to the M.H. for sanction to borrow £4,332 for sewage disposal works.

OUTWELL, NORFOLK.—*Bridge.*— The Norfolk C.C. proposes to construct a bridge at Outwell, estimated to cost £1,200.

PENRITH.—*Reservoir.*—The U.D.C. has received sanction to their water supply scheme from the M.H. The scheme includes the construction of a reinforced concrete reservoir with a capacity of 1,000,000 gallons.

REDCAR.—*Houses.*—The T.C. has applied to the M.H. for sanction to erect 100 houses.

RHYMNEY.—*Houses.*—The U.D.C. propose to erect 90 houses.

ROTHERHAM.—*Sewage Disposal Works.*—The R.D.C. has applied to the M.H. for sanction to borrow £10,390 for new sewage disposal works at Brampton Bierlow.

RUNCORN.—*Road.*—The Cheshire C.C. has under consideration an application from the Runcorn R.D.C. for a grant towards the construction of a road from Runcorn Railway Station to Sutton Weaver, estimated to cost £67,445.

STOKE-ON-TRENT. — *Houses.* — The Corporation proposes to construct 500 houses.

THURCROFT. — *Houses.* — The Rotherham R.D.C. proposes to erect 100 houses on the Katherine Street site.

TORQUAY.—*Sea Defence Works.*—The T.C. proposes to construct a concrete buttress wall 100 ft. in length, at Torbay Road, estimated to cost £2,800.

VENTNOR.—*Groynes.*—The U.D.C. proposes to construct two groynes at an estimated cost of £1,820.

WAKEFIELD.—*Houses.*—The Corporation proposes to construct 250 concrete houses within the next twelve months.

WALTHAMSTOW.—*Houses.*—The U.D.C. proposes to construct 74 houses, estimated to cost £51,000.

WEST LOTHIAN.—*Reservoir.*—The Linlithgow C.C. proposes to construct a reservoir on the Lyne Water.

WESTMORLAND.—*Concrete Roads.*—The Main Roads Committee is considering the construction of concrete roads through the Lake District.

WIMBORNE, DORSET. — *Houses.* — An offer to erect 20 concrete houses on the Leigh Park Estate has been received by the Wimborne U.D.C.

WORKSOP.—*Houses.*—The U.D.C. has decided to construct 100 houses in Retford Road.

YEOVIL.—*Houses.*—The T.C. has applied to the M.H. for sanction to borrow £2,998 in connection with the purchase of land for a housing site. The housing Committee has recommended that 100 houses be erected on the site.

TENDERS ACCEPTED.

BEDDINGTON (*Surrey*).—*Pavilion.*—The Beddington and Wallington U.D.C. has accepted the tender of Messrs. A. A. Secrett, Ltd., Wallington, at £706, for the construction of a brick and concrete pavilion.

BRIDLINGTON.—*Shelters.*—The T.C. has accepted the tender of the Whitehall Concrete Co., Leeds, at £4,670, for the construction of shelters on the Beaconsfield estate.

BROADSTAIRS. — *Water Tower.* — The U.D.C. has accepted the tender of Messrs. G. Rice & Son, Margate, at £8,075 6*s*. 5*d*., for the construction of a reinforced concrete reservoir tower and tank.

CARLISLE.—*Retaining Wall.*—The T.C. has accepted the tender of Messrs. John Laing & Son, Carlisle, at £1,138, for the construction of a concrete retaining wall at the sewage disposal works.

CHEADLE.—*Sewage Works.*—The R.D.C.

has accepted the tender of Mr. J. Hurst, Cheadle, at £3,221, for work in connection with the sewerage scheme at Kingsley Holt.

DUNDEE.—*Wharf.*—The Harbour Trustees have accepted the tender of the Yorkshire Hennebique Contracting Co., Ltd., Dundee, for the construction of an extension to the new wharf.

EXMOUTH.—*Engine Sheds.*—The Southern Railway Company has accepted the tender of Messrs. A. Jackaman & Sons, Ltd., for the construction of ferro-concrete locomotive sheds at Exmouth.

EYE.—*Sewerage Works.*—The Peterborough R.D.C. has accepted the tender of Messrs. J. Guttridge & Sons, Peterborough, at £2,148, for the construction of the sewage disposal works at Eye.

GRAVESEND.—*Tanks.*—The T.C. has accepted the tender of Messrs. G. E. Wallis & Sons, Ltd., Maidstone, at £23,797, for the construction of reinforced concrete tanks and sundry works at the sewage outfall works at Denton Marshes.

HERTFORD.—*Sewerage Works.*—The Corporation has accepted the tender of the Standard Construction and Maintenance Co., Swansea, at £14,855 16*s.* 2*d.*, for the construction of the first part of the new sewerage works.

LEEDS.—*Sewerage Works.*—The Corporation has accepted the tender of Messrs. Henry Atkinson & Sons, Ltd., at £24,018, for the erection and sinking of reinforced concrete cylinders required for the foundations of the new sewage tanks at Knostrop.

LICHFIELD.—*Concrete Works.*—The R.D.C. has accepted the tender of Mr. J. R. Deacon, Lichfield, at £1,179, for the construction of concrete works and filter beds at the Whittington sewage disposal works.

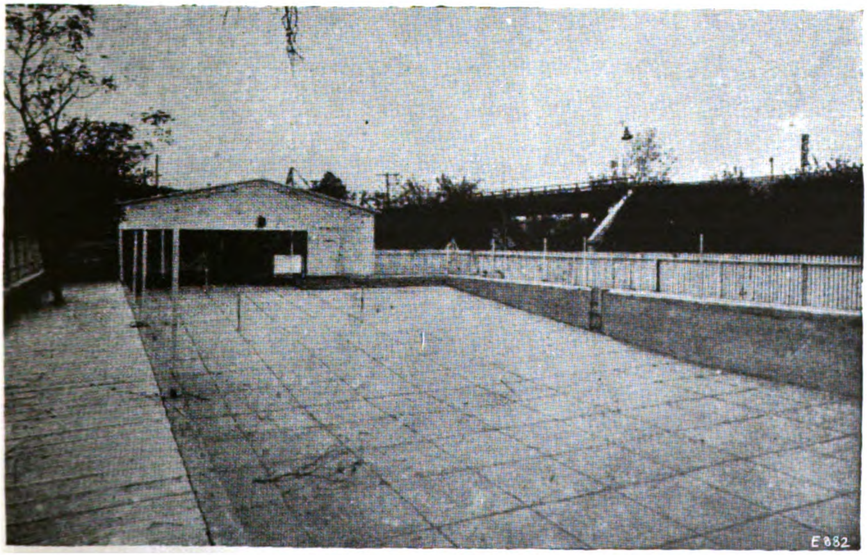
PERSHORE, WORCS.—*Bridge.*—The Worcestershire C.C. has accepted the tender of Messrs. Hobrough & Co., Gloucester, at £15,859 15*s.* 6*d.*, for the construction of a ferro-concrete bridge over the River Avon at Pershore.

RICKMANSWORTH.—*Houses.*—We understand that Messrs. Concrete Manufacturers (No. 1 London), Ltd., Brimsdown, will erect 21 houses at Rickmansworth, at a cost of about £420 each.

ROTHESAY.—*Sewerage Works.*—The T.C. has accepted the tender of Messrs. P. M'Bride & Co., Port Glasgow, at £50,235, for carrying out the new sewerage scheme.

SALTASH.—*Improvements.*—The Corporation has accepted the tender of Mr. W. H. Rothery, Saltash, at £2,525, for alterations and renovations at the Guildhall, including a new reinforced concrete gallery.

SHEFFIELD.—*Bridge.*—The C.C. has accepted the tender of Messrs. Thomas Wilkinson & Sons, at £6,100, for the con-



A CONCRETE SWIMMING POOL.

struction of a reinforced concrete bridge over the Sheaf at Charlotte Road.

SHEFFIELD.—*Bridge.*—The C.C. has accepted the tender of Messrs. A. Waddington & Son, at £4,194, for the construction of a reinforced concrete bridge over the Sheaf at Rydal Road.

SHEFFIELD.—*Foundations.*—The T.C. has accepted the tender of Messrs. G. Longden & Son, at £2,199, for the construction of concrete foundations at the Neepsend Generating Station.

SOUTH SHIELDS.—*Concreting.*—The T.C. has accepted the tender of Messrs. G. Thornton & Co., at £508 12*s.*, for concreting in back Alnwick Road.

STRETHAM FERRY.—*Bridge.*—The Isle of Ely C.C. has accepted the tender of Messrs. Baldry, Yerburgh and Hutchinson, Ltd., at £6,503, for the construction of a ferro-concrete bridge at Stretham Ferry.

WHALEY BRIDGE. — *Bridge.* — The U.D.C. has recommended for acceptance the tender of the Reinforced Concrete Construction Co., at £2,065, for the reconstruction of the canal bridge on Thornsett Road.

RECENT PATENT APPLICATIONS.

210,154.—W. L. H. Roberts: Portland-cement compositions.

210,202.—J. L. Musgrave and R. G. Crittall: Heating and cooling of reinforced concrete columns, walls, floors and ceilings.

210,297.—British Reinforced Concrete Engineering Co., Ltd., and E. B. Hall: Reinforcement for concrete road foundations.

210,366.—L. G. Patrouilleau: Manufacture of bauxite cements free from metallic impurities.

210,470.—R. F. Wilkins and H. Chandler: Composition for facing walls and partitions.

210,700.—J. Newell: Concrete building-blocks.

210,872.—V. Maggio: Press-moulding apparatus for the manufacture of objects from concrete.

211,333.—H. McKinnon: Manufacture of concrete or breeze slabs.

TRADE NOTICES.

Mr. George Richwood, who was at one time Sales Manager of the Machinery Department of Messrs. Millars' Timber & Trading Co. Ltd., and more recently Manager of the Machinery Department of Messrs. Gaston, Ltd., has now been appointed Sales Manager for the Construction Machinery Department of Messrs. John Fowler & Co. (Leeds), Ltd. This department embraces concrete mixers and placing equipment, stone crushing and screening plant, road graders, etc.

Messrs. McCall & Co. (Sheffield), Ltd., iron and steel merchants, of Sheffield, have removed to Mazda Buildings, Sheffield. The telephone number (Central 4113) and telegraphic address (Versatile, Sheffield) remain unaltered.

Messrs. Ruston & Hornsby, Ltd., engineers, have changed their London address from Queen Victoria Street to Imperial House, 15–19 Kingsway, W.C.2. (Telephone: Gerrard 5866; Telegrams: Ruston Westcent London.)

The British Reinforced Concrete Engineering Co., Ltd., are removing to more commodious premises on April 12, and their new address will be: King's Buildings, Smith Square, Westminster, S.W.1. The telephone numbers will be:—Roads Dept., Victoria 7833; Constructional Dept., Victoria 7866 and 3218.

Single Copies, 1s. 6d. nett. *Annual, Post Free, 18s.*

MAY 23 1924

CONCRETE AND CONSTRUCTIONAL ENGINEERING

MAY 1924 VOL. XIX. No. 5

A MONTHLY JOURNAL for Engineers, Architects, Surveyors and Contractors and all interested in Cement, Concrete, Reinforced Concrete, Fire-Resisting Construction and Structural Steel.

ISSUED MONTHLY

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By P. CALFAS, Ing. E.C.P.

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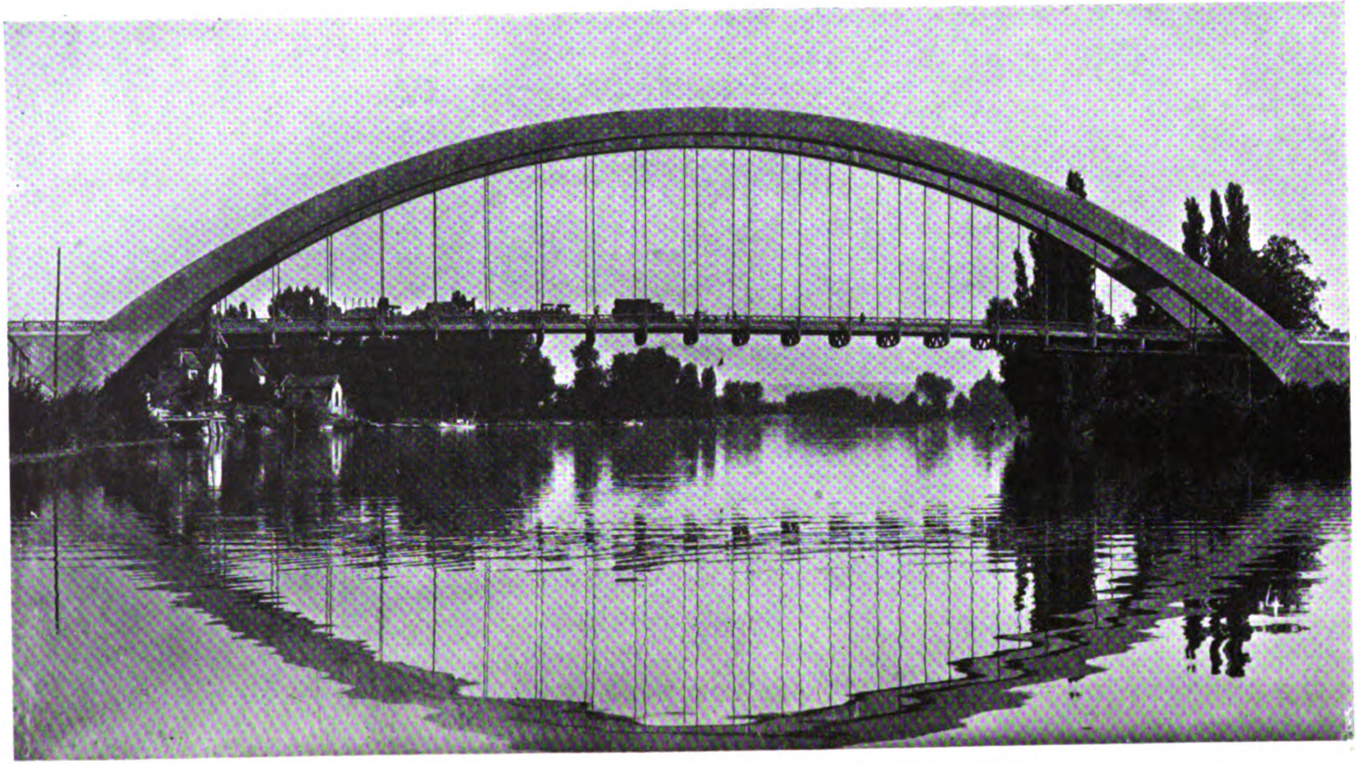


REINFORCED CONCRETE BRIDGE AT ST. PIERRE-DU-VAUVRAY.

(*See page* 281.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIX. No. 5. LONDON, MAY, 1924

EDITORIAL NOTES.

THE IDEAL PORTLAND CEMENT.

IT is well that those interested in the manufacture of cement and the development of concrete should from time to time ask themselves the question, " What are the properties of an ideal cement ? " The fact that ordinary working operations have been adjusted to correspond with the properties of the cement now produced may lead to the possibility of any marked improvement being forgotten, and this in its turn may cause an absence of effort for improvement. Without attempting a comprehensive definition, an ideal cement may be described as one which after mixing with water remains inert for a period of an hour and then hardens so rapidly that at the end of another hour it possesses the toughness of granite and the tenacity of steel. The setting properties would be constant even though the temperature might vary from 25° F. to 85° F., and frost would have no effect. The cement would be capable of prolonged storage in the British climate without change of setting properties or deterioration in any way. There would be no contraction or expansion of the set cement except that due to temperature changes. The cement would not be affected by the presence of mud, loam, sulphur, or coal in any aggregate mixed with it.

It will be observed that some of these requirements are contrary to the laws of nature and therefore impossible of production. For example, the setting of cement can hardly be other than a chemical reaction, and it is consequently bound to be susceptible to the effect of temperature ; and, again, a cement that sets by interaction with water can hardly remain unaffected by contact with a damp atmosphere during prolonged storage.

The other ideal properties indicated are, however, within the bounds of possibility. The property of attaining maximum hardness within two hours of gauging is considerably nearer realisation since the advent of aluminous cement, and we do not suppose that the latter cement has reached finality in its development. The change in methods of construction which would result from the rapid hardening properties attributed to the ideal cement would be revolutionary. Cement users have so accommodated themselves to the behaviour of the slow hardening cements of twenty years ago that there seems some reluctance to take the full advantage of even the rapid hardening cements that are now available, and the possibilities resulting from the use of a cement of the ideal properties described are on a far more extensive scale. This property of almost instantaneous hardening is, however, one that seems quite possible of realisation. The setting of cement is a chemical reaction—namely the hydration of certain compounds—and there is no reason why means should not be discovered of accelerating this reaction. The hydration or slaking of lime can be made almost instantaneous, why should not cement be brought into line ?

The ideal property of freedom from contraction or expansion is another that is not theoretically impossible of realisation. The cracking that is sometimes noticeable on large concrete surfaces where the proportion of cement is large arises from the fact that the amount of water needed to produce a plastic concrete or mortar is more than can be absorbed by the cement, and when the excess of water evaporates there is a tendency to contraction that can only be overcome by taking special precautions. If, however, a cement could be produced that would absorb chemically all the water used in gauging then there should be no contraction. This is a problem that should not be impossible of solution, and will no doubt be an object of investigation by research workers of the future. Other ideal properties that have been mentioned are the toughness of granite and the tenacity of steel. These may appear to be properties well beyond reach, but when it is remembered that the compressive and tensile strengths of commercial cement have doubled during the past twenty years it would be unwise to suggest any limits in this direction. It will be obvious, however, that the property of tenacity would be of small value if contractive tendencies likely to lead to cracking were not removed.

Finally, it is not impossible that in course of time cements will be made which will be less susceptible to the effects of dirty and sulphury aggregates, or it may be possible by the addition of some chemical to nullify the effect of these now deleterious materials.

SCULPTURE IN CEMENT.

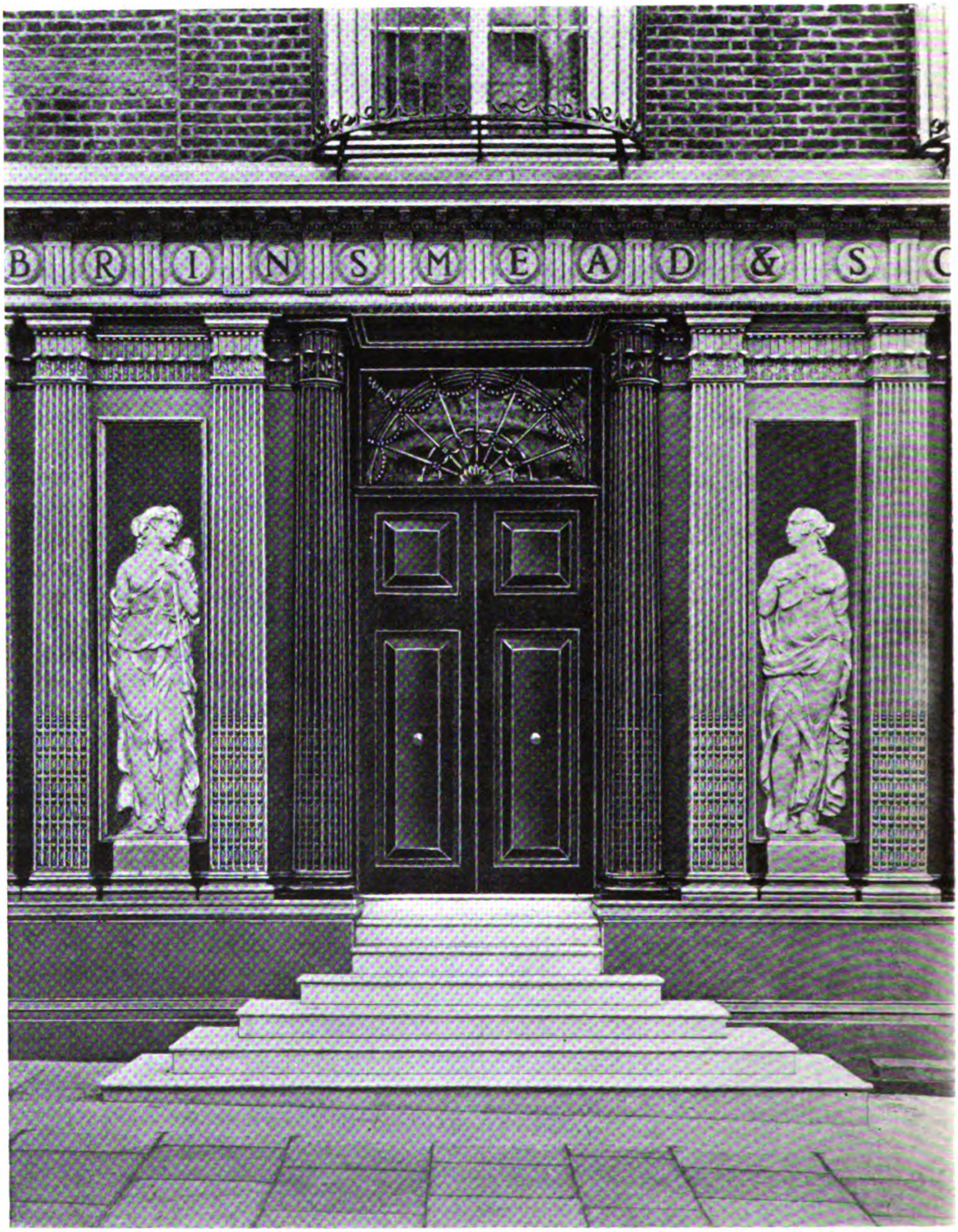
ONE has heard so much of the headway which has been made in America in the application of cement and concrete to the sculptor's art that it is gratifying to be able to illustrate in this issue such fine examples of cement sculpture carried out in this country as the figures by Mr. Gilbert Bayes on Messrs. Brinsmead's new premises and Mr. Doyle Jones' symbolic figure exhibited at the Building Trades Exhibition last month. In his suggestive article in this issue Mr. T. P. Bennett, F.R.I.B.A. (architect of Messrs. Brinsmead's building), makes the following remarks on the architecture of concrete buildings, which we heartily endorse : " Concrete and steel are with us as permanent constructional materials. Because of their high structural value they must of necessity remain and must come more and more into use. Cement is the natural clothing for a steel and concrete structure, and architects must undoubtedly study more and more an architecture of cement. There are, of course, fundamental differences in the proportion of supports, lintels and openings in concrete-steel buildings from those which belong to masonry buildings. This difference will, in time, cause the evolution of a new form of design. The change from masonry proportions to steel proportions is revolutionary, and presents a problem which has no parallel since the days of the development of Greek art in 400–500 B.C. when the Greeks succeeded in throwing off the pseudo wood forms of the stone buildings of their predecessors and of the pseudo mud-and-reed forms of the Egyptians and produced a finished style which frankly expressed masonry. Minor achievements have taken place at other times and in other places, such as the development of Flemish brickwork and of English half-timber construction. It remains, however, for this generation to evolve an architecture of steel and cement, and the problem is full of difficulties. Should the new forms of building be severe, devoid of ornament, colourless, or should they be rich, interesting and full of colour ? Should the ornament that is used be modelled, incised or applied ? Should the colour be mixed with the material as colouring pigment or should it be applied as paint ? Should the whole of the enrichment be obtained with cement and paint, or should part of the effect depend upon iron, wood, tiles, marble and mosaic ? These are a few of the problems with which the designer is confronted and for which he must provide a solution. This is the province of the architect with artistic skill, constructional knowledge, sympathy with and interest in the new material and an ability to co-ordinate his work with that of engineers and artists."

PORTLAND CEMENT RESEARCH.

We have received from the British Portland Cement Research Association a copy of their Pamphlet No. 3 entitled "The Exothermic Reaction of Portland Cement Clinker Formation." The subject matter of the pamphlet is not of popular interest but it indicates that the British Portland Cement Research Association is pursuing the object we have previously referred to, which is largely the justification for their existence, viz., endeavours to discover means by which the manufacture of Portland cement can be improved to produce a better material at a lower cost.

In the course of manufacture of Portland cement the mixture of raw materials—chalk and clay or chemically similar materials—is heated in a kiln to a degree just short of fusion so as to produce what is known as cement clinker. During the first part of the heating process heat is absorbed for the evaporation of water and for the decomposition of carbonate of lime, but in the latter part of the time during which the material is in the kiln, heat is given out, or, in technical language, the reactions in the kiln are first endothermic and finally exothermic. The fuel consumption in a cement kiln, accounts for approximately one-third of the cost of production, and the object of the investigation in this department of manufacture by the British Portland Cement Research Association was to discover the possibilities of reducing this important item of cost. The inquiry involved the analysis of the distribution of the heat put into a cement kiln, and in this connection the heat given out by the exothermic reaction had to be taken into account.

The pamphlet before us gives a resumé of all the known literature on the subject and gives full translations of some of the more important Austrian, German, and Russian researches on the subject. The variety of opinion upon the subject is shown by the fact that the results given by seven different investigators for the value of the exothermic reaction range from nearly six tons of coal per 100 tons of clinker produced down to a quarter of a ton. A study of the literature leads to the conclusion that the correct figure is 1½ tons of coal per 100 tons of clinker ; that is to say, if the exothermic reaction did not occur the fuel consumption for cement burning which is now about 30 per cent. would be 1½ per cent. higher.



[*Messrs. Bennett & Hossack, Architects; Mr. Gilbert Bayes, Sculptor.*

MESSRS. BRINSMEAD'S NEW PREMISES: SHOWING CEMENT SCULPTURE. (*See p.* 275.)

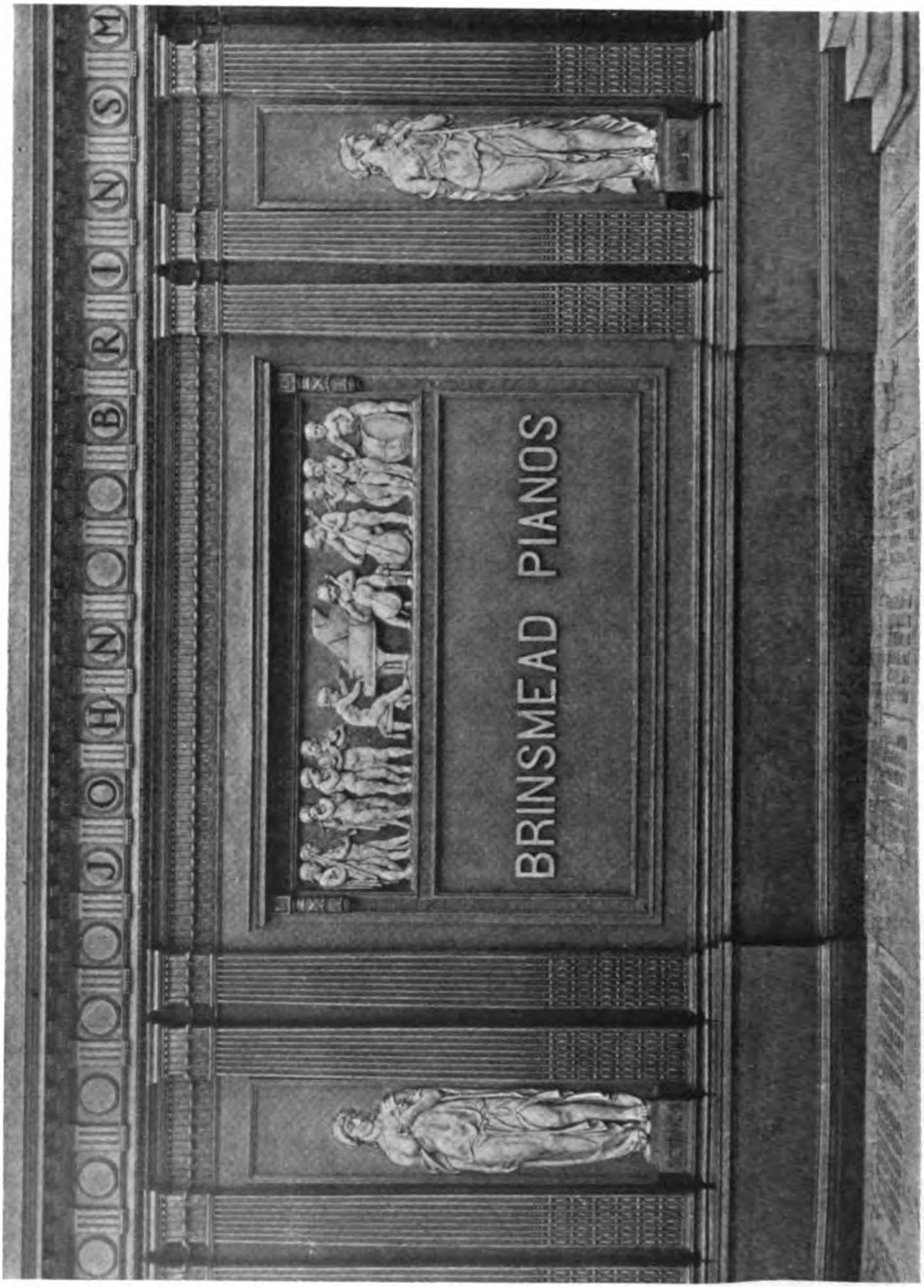
SCULPTURE AND DECORATION EXECUTED IN CEMENT.

BY T. P. BENNETT, F.R.I.B.A.

THE demolition of Nash's Regent Street calls attention to the cement fronts of the Regency period, and perhaps indicates that the material was not so poor as some would have us imagine. These old stucco elevations have a distinct charm and interest of their own. They are not stone fronts, and do not pretend to be. Many of them are enriched with ornament which is essentially plastic in design and execution. The quiet distinction which they gain from the handling of their detail is undeniable. It is almost surprising to find that cement columns have stood for so long and have lasted so well. There has never been any evidence of excessive or even substantial repair, and paint has been the only protection most of the work has had.

Further afield other fine examples of stucco buildings come to mind, of which the most famous is perhaps the Athenæum Club. In this case Decimus Burton conceived a fine architectural treatment with a simple façade, a columnar portico and a rich frieze in relief modelled after its famous prototype in the Parthenon. The Athenæum has been preserved by means of paint, but has not otherwise been extensively repaired, yet it stands to-day to all appearances as sound and satisfactory as when it was first built. Its painted cement front is still a magnificent piece of architecture and makes a fine and dignified building, no wit less fine because it is not in stone. Incidentally, paint may be readily renewed and thus the smoke and dirt of the London atmosphere is periodically eliminated from the façade.

Concrete and steel are with us as permanent constructional materials. Because of their high structural value they must of necessity remain and must come more and more into use. Cement is the natural clothing for a steel and concrete structure, and architects must undoubtedly study more and more an architecture of cement. There are, of course, fundamental differences in the proportion of supports, lintels and openings in concrete-steel buildings from those which belong to masonry buildings. This difference will, in time, cause the evolution of a new form of design. The change from masonry proportions to steel proportions is revolutionary, and presents a problem which has no parallel since the days of the development of Greek art in 400–500 B.C. when the Greeks succeeded in throwing off the pseudo wood forms of the stone buildings of their predecessors and of the pseudo mud-and-reed forms of the Egyptians and produced a finished style which frankly expressed masonry. Minor achievements have taken place at other times and in other places, such as the development of Flemish brickwork and of English half-timber construction. It remains, however, for this generation to evolve an architecture of steel and cement, and the problem is full of difficulties. Should the new forms of building be severe, devoid of ornament, colourless, or should they be rich, interesting and full of colour? Should the ornament that is used be modelled, incised or applied? Should the colour be mixed with the material as colouring pigment or should it be applied as paint? Should the whole of the enrichment be obtained with cement and paint, or should part of the effect depend upon iron, wood, tiles, marble and mosaic? These are a few of the problems with which the designer



[Messrs. Bennett & Hossack, Architects; Mr. Gilbert Bayes, Sculptor.

MESSRS. BRINSMEAD'S NEW PREMISES: SHOWING CEMENT SCULPTURE.

is confronted and for which he must provide a solution. This is the province of the architect with artistic skill, constructional knowledge, sympathy with and interest in the new material, and an ability to co-ordinate his work with that of engineers and artists.

With these points in mind, the attempt made in Messrs. Brinsmead's new premises to produce a sound and interesting front in cement is not without interest. It is true that the harmonising of the proportion of the parts with steel forms was only slightly called into question, but the use of the material has been extended in many ways, and is to this extent an experiment. It is being regarded by many as a successful experiment, and as such may be critically examined in detail.

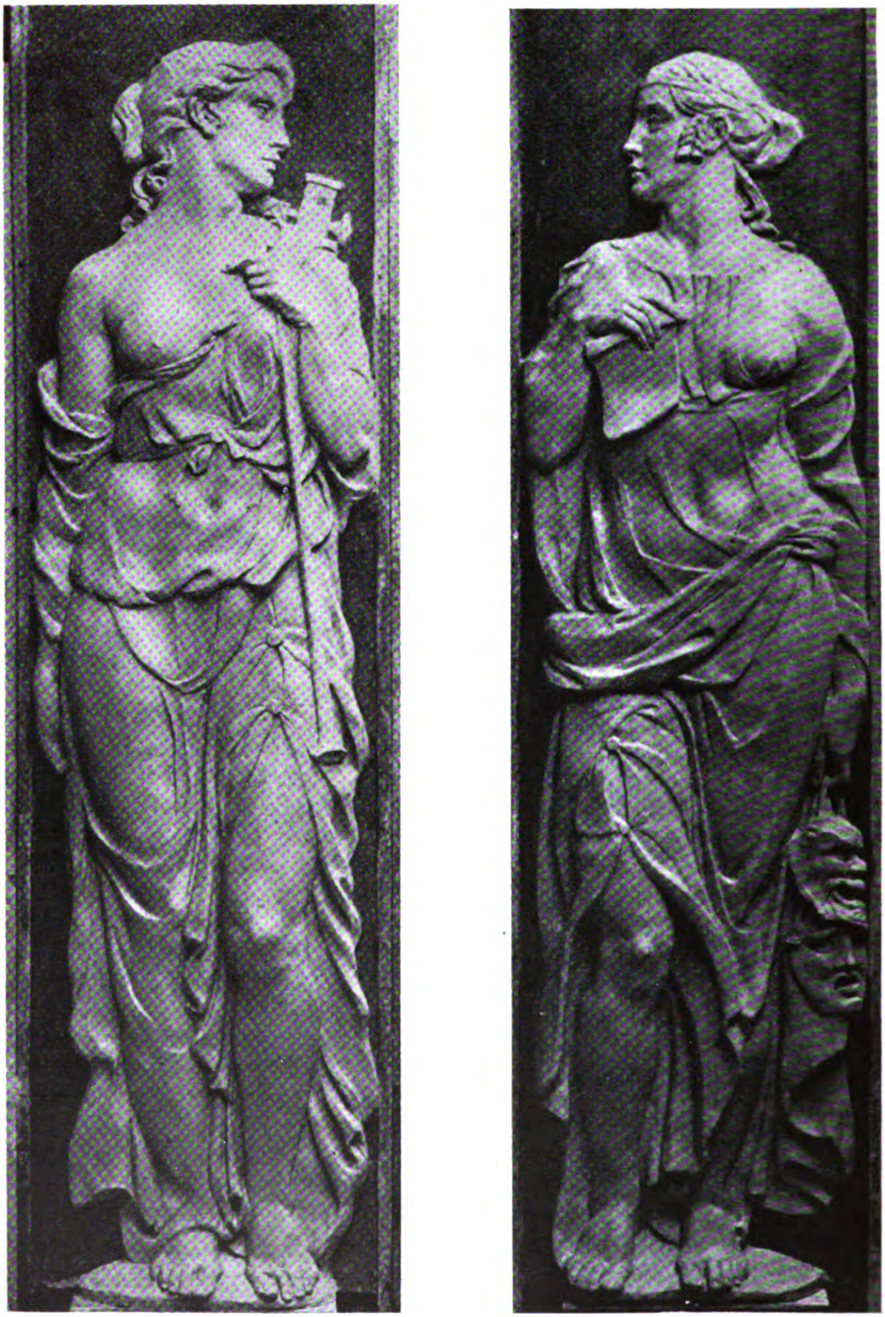
In the first place it should be noted that the cement is placed next to mahogany columns, mahogany doors, and a mahogany window, while use is made of iron grilles in the fanlight to the doors and to the small boiler house window in the basement.

There is no incongruity in this joint use of materials; rather it seems to add to the interest of the whole, and it is to be doubted whether this harmony would have been secured if the front had been stone instead of cement. To this extent the use of the cement is a gain because it allows the introduction of the texture and colour of the wood columns, and the final effect is thereby enhanced.

The next point of interest lies in the application of the material. In this case the cement was applied to old brickwork which was hacked and raked out to form a key. Backing was applied of cement and sand in the proportion of 1 of cement to 1 of washed sand. The mouldings were then run in cement and sand in the same proportion, but skimmed over with a finishing coat of neat cement. The large projections were formed with rods and expanded metal lathing rendered with a 1 : 2 backing, the mouldings being run in 1 : 2 and finished with neat cement. The plinth is backed out with brickwork and then treated as the plain surfaces mentioned above. The pilasters were pre-cast in cement and sand (1 : 2) and finished with a neat face. The relief ornaments were cast in cement and cemented into grooves left in the plain work to receive them. In the case of the figures, clay models were prepared by Mr. Gilbert Bayes, the well-known sculptor, who was responsible for the whole of the work. These clay models were moulded in solid fibrous plaster moulds from which the cement casts were taken. The cement figures were reinforced with light mesh expanded metal and iron rods. The pre-cast figures and frieze had a backing of cement and sand about 1 in. in thickness, and were then built into the work and the edges made good to the surrounding mouldings, etc. The architectural ornament was cast in gelatine moulds to allow for the undercut surfaces.

The cement proved to be very slow setting in the bad weather experienced during the execution of the work, and this caused a considerable amount of delay. It was necessary to allow each coat to set hard before applying the next coat, or it would fail to hold. One or two portions of the work broke away and had to be replaced. Work was stopped in frosty weather, but when frosts took place only at night the work was allowed to proceed as soon as the temperature rose in the morning, generally about 10.30–11 a.m.

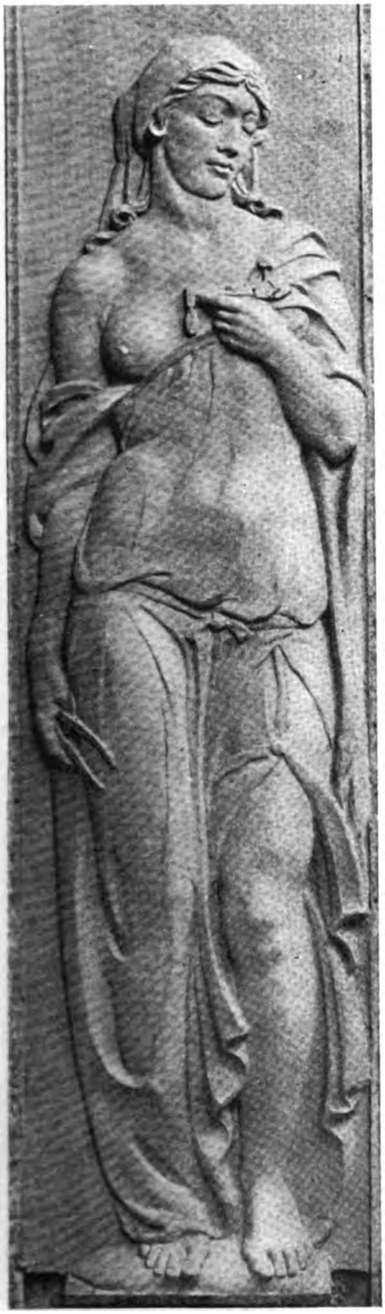
After the cement had set it was coated with cement paint and then with ordinary oil paint, finally being finished with two coats of varnish.



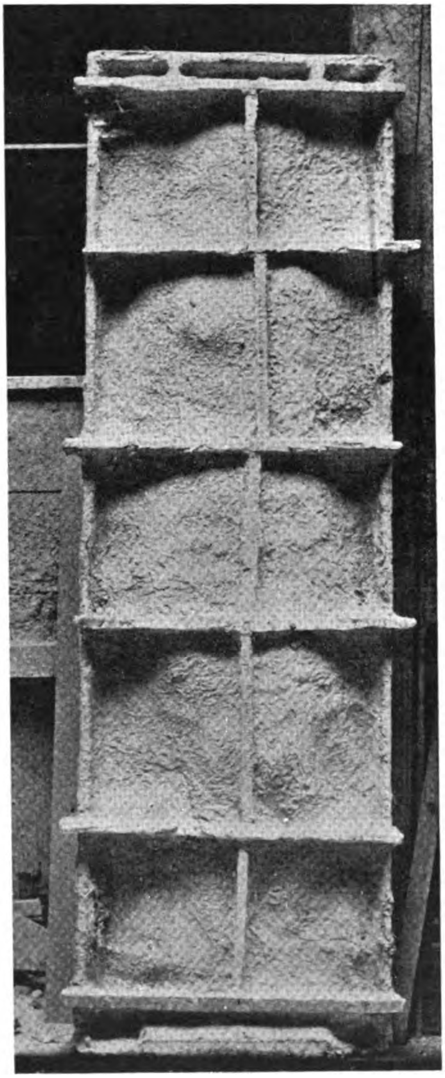
[*Mr. Gilbert Bayes, Sculptor.*

"MUSIC." "ART."

CEMENT SCULPTURE ON MESSRS. BRINSMEAD'S NEW PREMISES.



"SCIENCE."



MOULD FOR CASTING CONCRETE FIGURES ON MESSRS. BRINSMEAD'S PREMISES.

CEMENT SCULPTURE ON MESSRS. BRINSMEAD'S NEW PREMISES.

No trouble has been experienced from the action of the cement upon the paintwork, although a slight effervescence occurred in one or two places soon after the paint was applied. This effervescence died down and has not since recurred. The colour scheme employed is ivory white for the sculpture, a mixture of umber and burnt sienna for the general surface, and burnt sienna for the background behind the figures.

The cast ornaments and enrichments and the casting of the figures were executed by Messrs. G. Jackson & Sons, Ltd. The plaster-work to the front and the decorative work by Messrs. Green & Abbott, Ltd. Mr. Gilbert Bayes was the sculptor and Messrs. T. P. Bennett & Hossack the architects.

CEMENT CONGRESS.

On April 22–24 an International Cement Congress was held at Olympia, under the auspices of the Institution of Structural Engineers.

Among the delegates were:

Dr. Stanton (National Physical Laboratory).

Dr. Geoffrey Martin (Society of Chemical Industry and the Faraday Society).

Dr. David Prentice (Society of Chemical Industry).

Mr. H. K. G. Bamber (British Portland Cement Research Association and the British Engineering Standards Association).

Mr. Max Clarke (Royal Institute of British Architects).

Mr. H. D. Searles-Wood (Royal Institute of British Architects).

Mr. E. Willis (Royal Sanitary Institute).

M. T. J. Gueritte (Société des Ingeniers Civils de France and the Society of Engineers).

Mr. W. C. Unwin (American Society of Civil Engineers).

Mr. W. S. Jones (American Concrete Institute).

Professor L. Luiggi (Italian Society of Civil Engineers).

Messrs. J. W. Maas and W. C. van Manen (Koninklijk Instituut van Ingenieurs).

Mr. A. Ingerslev (Danish Institution of Civil Engineers).

Herr F. Selmer (Den Norske Ingenierforening).

Herr Gustav Berg (Ingeniorsvetemskapsakdemion and Svenska Betongforeningen).

Professor A. Paris (Association of Civil Engineers of Switzerland).

M. O. Lepersonne (Assn. des Ingenieurs sortis de l'Ecole de Liege).

Mr. T. Wallis (Society of Architects).

Sir Alexander Gibb (Institution of Chemical Engineers).

Mr. L. F. M. Leese (Institution of Chemical Engineers).

Mr. J. M. Moncrieff (Assn. of Consulting Engineers).

Mr. E. W. Monkhouse (Assn. of Consulting Engineers).

Mr. A. Dryland (Institute of Transport).

Mr. J. S. Alford (Institution of Sanitary Engineers).

Mr. C. E. C. Lowry (National Federation of Building Trades Employers).

Mr. J. A. Gould (Architects' and Surveyors' Assistants' Professional Union).

Mr. J. Mitchell (Architects' and Surveyors' Assistants' Professional Union).

Professor C. H. Desch (The Chemical Society and the Faraday Society).

Mr. F. E. Wentworth-Sheilds (British Engineering Standards Association).

Lieut.-Col. D. K. Edgar (Institution of Royal Engineers).

Lieut.-Col. J. G. Fleming (Institution of Royal Engineers).

Mr. D. B. Butler (Society of Engineers).

Mr. J. E. Barnard (Royal Microscopical Society).

Mr. W. E. Watson-Baker (Royal Microscopical Society).

On April 22 the delegates and others were received by Mr. James Petrie (President), and afterwards conducted round the Exhibition, following which they were entertained to luncheon.

In the evening a large number of papers relating to the manufacture and uses of cement, contributed by British and foreign delegates, were discussed, and on the following days the Kent Portland Cement Works and the British Empire Exhibition were visited.

REINFORCED CONCRETE BRIDGE OF 432 FT. SPAN.

By P. CALFAS, Ing. E.C.P. (Paris).

THE longest reinforced concrete arch bridge in the world has recently been opened to traffic in France (*see Frontispiece*). This bridge is not only remarkable on account of its exceptionally large dimensions, but also on account of its shape and of the methods adopted for its construction.

The new bridge replaces an old road bridge connecting St. Pierre-du-Vauvray with Andé across the Seine (in the Eure Department), and consists of two arches imbedded in abutments and having a clear span of 131 m. 80 (432 ft. 6 in.). The rise above the level of the spandrel is 25 metres (82 ft.).

Before the construction of this bridge the largest reinforced concrete arch bridge in existence was that across the Mississipi at Minneapolis, with a span of 400 ft.

The great rise above the level of the spandrel was given to the St. Pierre bridge so as to diminish the lateral thrust on the foundations. The neutral axis may be said to coincide with the funicular polygon for dead loads, and thereby bending moments are reduced to a minimum. Under these conditions a comparatively small amount of reinforcement was required to ensure the safe resistance of the construction. The arches of the bridge have a hollow rectangular cross-section of uniform width 2 m. 50 (8 ft. 2½ in.), the depth varying from 4 m. 10 (13 ft. 6 in.) at spandrel level to 8 ft. 2½ in. at the crown.

The thickness of the walls, or sides, of the arch varies proportionately from the base to the crown. The thickness of the lower face and of the top face ranges between 0 m. 33 and 0 m. 36 (13 in. and 14 in.), and the thickness of the vertical faces is 0 m. 20 (8 in.)

Both these arches therefore represent hollow tubes whose sides are comparatively thin, and they could thus be endowed with great rigidity for a relatively small total dead weight. The portion of the arches below the flooring on which the traffic is carried is in solid concrete to form the embedment.

The flooring of the bridge below the arch is 8 m. 80 (29 ft.) wide, and is supported by lattice reinforced concrete cross-girders, the distance between them being 5 m. 24 (17 ft. 2 in.). These cross-girders are suspended to the arches by means of very small tie-beams, each of which is made up of forty steel bars of 10 mm. (13/32 in.) diameter encased in concrete so as to form a reinforced concrete tie-beam 0 m. 14 by 0 m. 14 (5½ in. by 5½ in.) in section. The concrete simply protects the steel bars from rust.

The suspenders are fixed in the interior of the arch to a cross bulkhead which stiffens the arch vertically at each suspender, and the bars spread out and radiate in the bulkhead so as to ensure a perfectly solid grip. The bulkheads are strengthened with other reinforcing bars passing through the lower face wall of the arch and coming up on both sides of the suspension system so as to be hooked in the vertical and top sides of the arch. Each bulkhead is provided with an aperture which allows for the passage of a man, thus ensuring thorough communication inside the arch.

The girders supporting the flooring are 1 m. 50 (5 ft.) deep and 0 m. 20 (8 in.) thick, and were pre-cast on the banks of the river and set in place afterwards. At both ends hollow spaces have been provided so as to allow for the hooking of

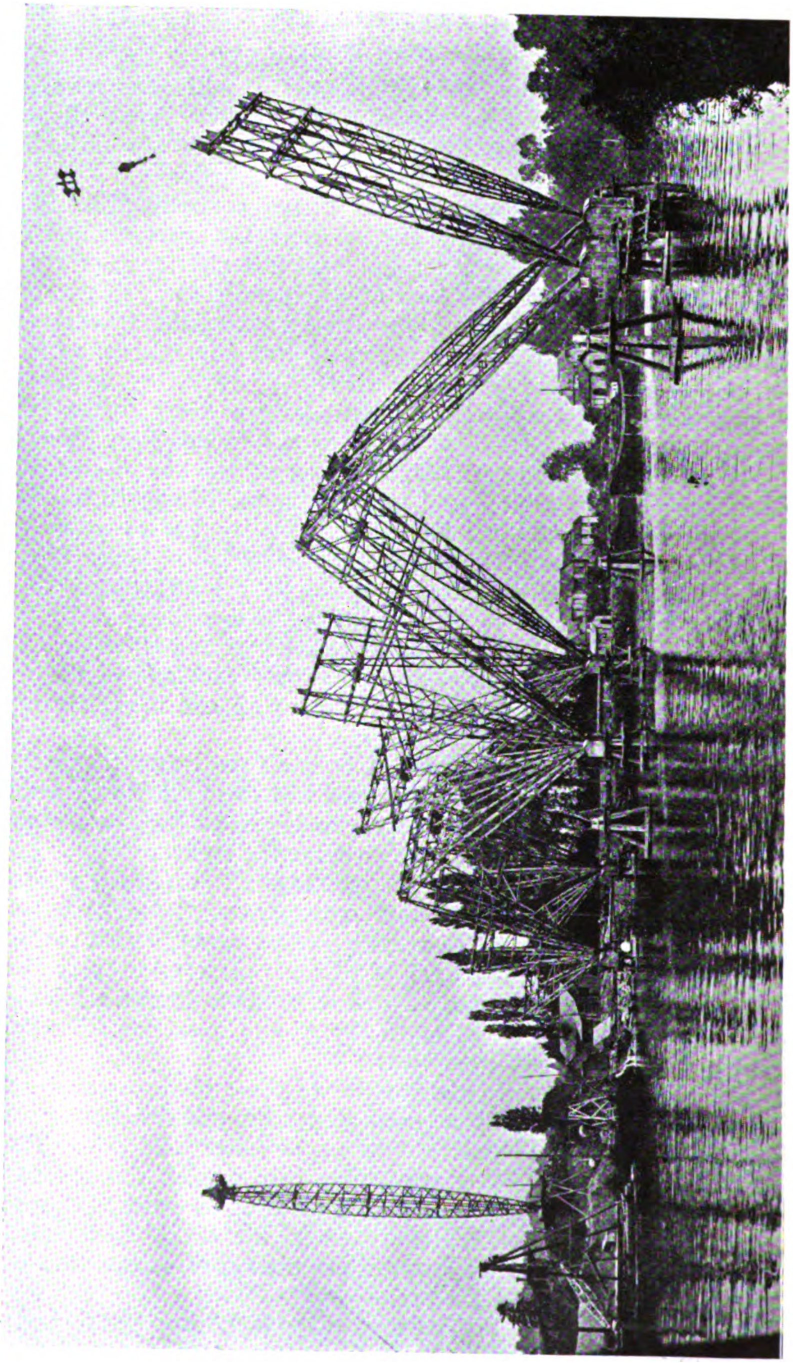


FIG. 1.—REINFORCED CONCRETE BRIDGE AT ST. PIERRE-DU-VAUVRAY.

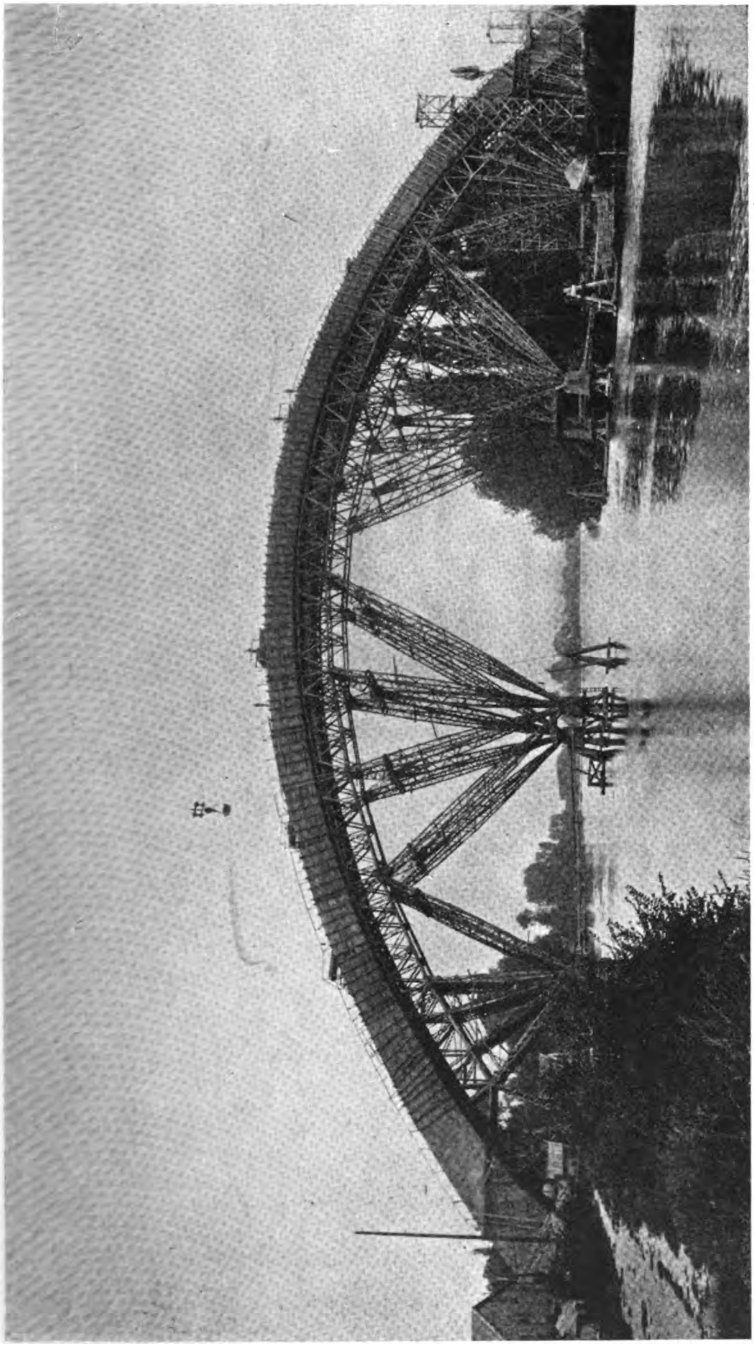


FIG. 2.—REINFORCED CONCRETE BRIDGE AT ST. PIERRE-DU-VAUVRAY.

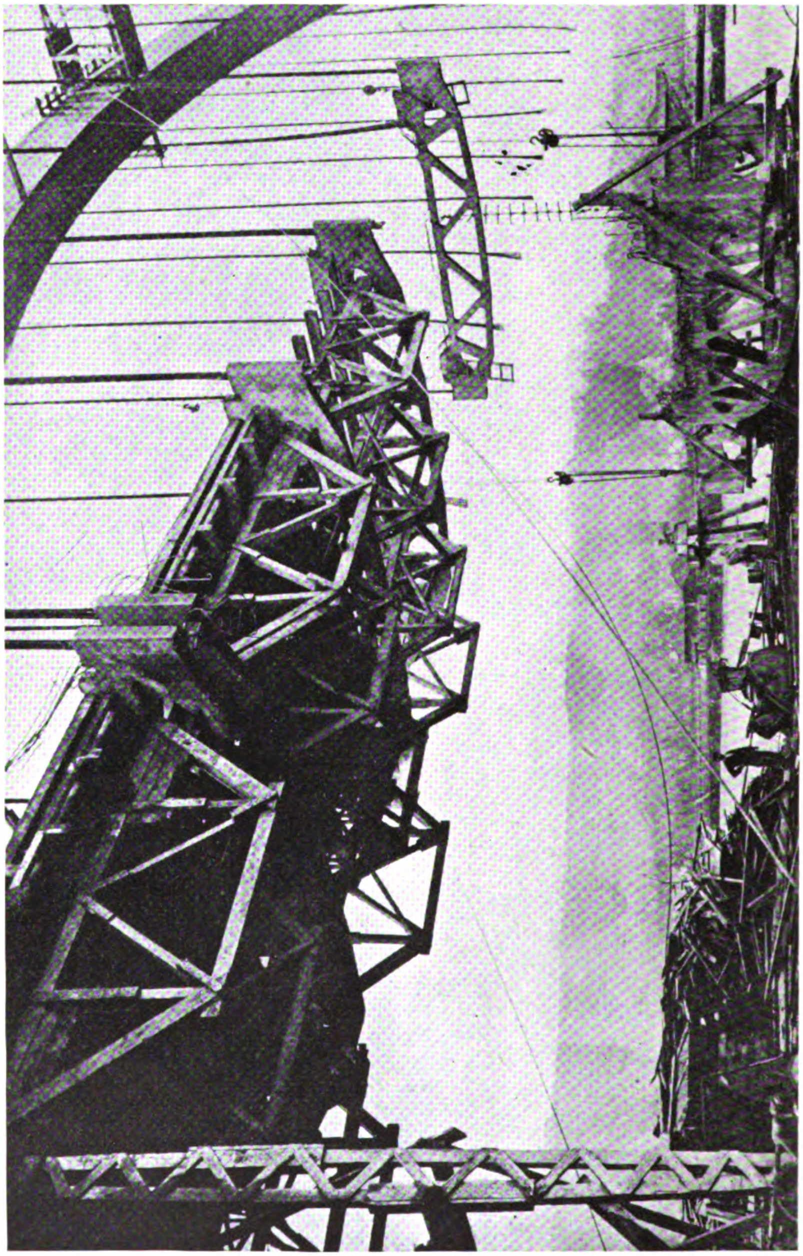


FIG. 3.—REINFORCED CONCRETE BRIDGE AT ST. PIERRE-DU-VAUVRAY.

the suspension bars, and these spaces were subsequently filled up with concrete.

The abutments of the bridge are built up on reinforced concrete caissons set in place on solid ground by means of compressed air. The arches are tied together only by two hollow beams near the spandrels at a height of about 5 metres (16 ft.) above the level of the roadway. Apart from these two ties the arches are completely independent from each other, and this fact contributes to give an appearance of lightness to the work. The ties are large in section, but the walls are very thin; the top and two sides are only 0 m. 08 ($3\frac{1}{8}$ in.) thick and the lower face, corresponding with the soffit of the arches, is 0 m. 10 ($3\frac{15}{16}$ in.) thick. The construction has been carried out upon latticed timber frames. The works had to be carried out without interrupting navigation service on the river, and therefore only two groups of dolphins were built in the river and two others close to the banks. Each group consisted of four bollards: two in the middle for supporting the formwork and two at the sides to serve as protection. The formwork rested upon a series of timber shear legs, as shown in *Fig* 2. For all framing, lagging, planking and shears the builders decided to use strong nails instead of bolts, it being considered that this system would give greater rigidity than bolts as it was thought the latter would soon give an oval shape to their holes when under load, thus causing deformation of the joints under the varying influences of dryness, humidity, or load variations.

The shear legs, or props, which supported the formwork were assembled on the side of the river and set in place by means of a cableway erected across the river. Each of the bollards set in the bed of the river was provided with four shears and each of those near the banks with three; twelve equidistant supporting points were therefore available for bearing the formwork, which consisted of a lattice arch made up of planks fixed in position by nails.

The lagging and planking of the arches had also been previously built up in panels and then brought to place by means of the cableway.

The concrete was mixed upon the side of the river and carried in tilting skips on the cable-way. The placing of the concrete was carried out in four stages: In the first stage the concrete of the under-side of the arch ribs was spread over the whole extent of the arches. In the second stage the concrete was poured half-way up the side walls of the arch. The third stage consisted in the completion of the side faces to their full height. At the fourth stage the top face was poured. In this way the frame was progressively loaded, and deformation that might have resulted through overloading at certain parts was prevented.

The concrete mixture was in the proportion of 590 lbs. of Portland cement for each cubic yard of concrete (350 kgs. per cubic metre), and was placed in a sufficiently fluid state to penetrate easily within the falsework in spite of the thinness of the covering. For ramming the concrete into place and ensuring its homogeneity compressed air vibrators, which gave a slight vibrating motion to the falsework, were used.

A unique feature of the work was the process adopted for removing the wooden frames. This system was originated by M. Freyssinet, and had previously been employed by him for the construction of two bridges, one across the Veurdre (in the Allier Department) and one at Villeneuve-sur-Lot. The usual method of lowering the frames below the arches is departed from, and the arches

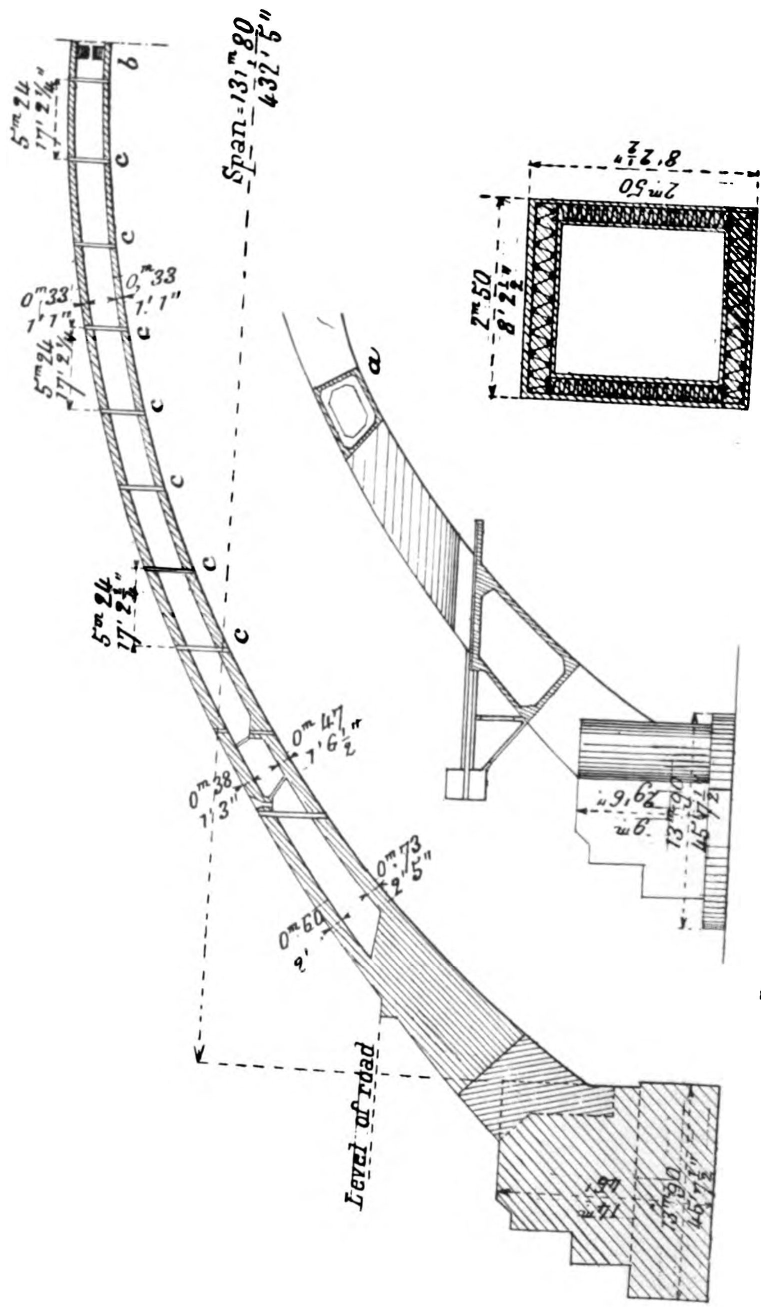


Fig. 4.—REINFORCED CONCRETE BRIDGE AT ST. PIERRE-DU-VAUVRAY.

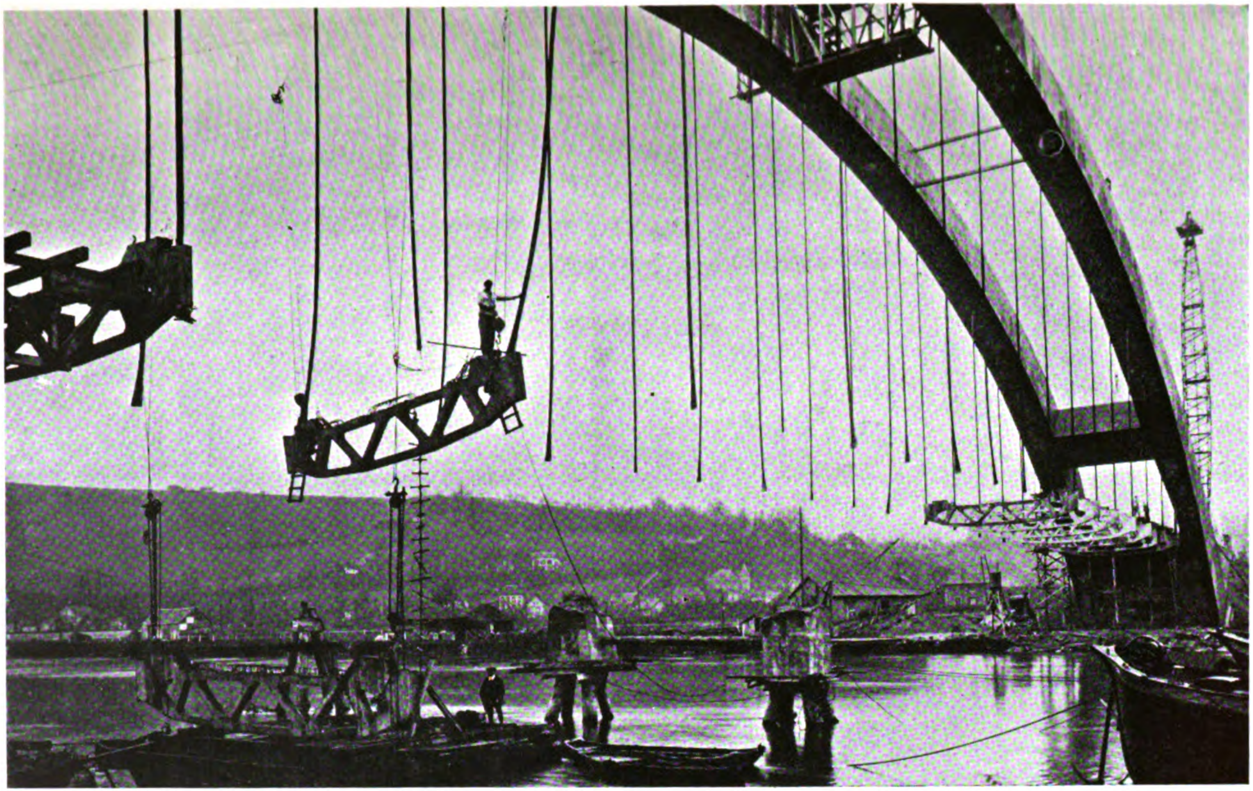


FIG. 5.—REINFORCED CONCRETE BRIDGE AT ST. PIERRE-DU-VAUVRAY.

are lifted above the framework. For that purpose each arch was constructed in two independent sections separated by a narrow space at the crown. In that space were placed hydraulic jacks, acting horizontally, with sufficient power to push apart slightly the two half-arches in raising them out of the formwork, working in a horizontal direction. In the intervening space reinforced concrete plates coated with wet cement were inserted to act as keys to the arches, and the joint closed up when the water was allowed to run out from the hydraulic jacks.

This process, which may seem to be rather complicated, possesses numerous advantages. In fact, the pressure existing at the crown of the arch may be tested, as it is the force exerted by the jacks which separate the half-arches. Moreover, it may be ascertained whether the shape of the arch is according to the design, and whether the neutral axis has undergone any deformation. If the neutral axis gets out of line through the loading process, or through the yielding of the formwork, it may be re-established according to the design by simply altering the thickness of the crown. This last advantage is by far the most important.

In constructing the Veurdre Bridge, whose arches are of 72 m. 50 (238 ft.) span, the free space had not even been filled in with concrete at the crown of the two arches, and metal liners or plates were simply introduced leaving a free space for the jacks. The adoption of this device enabled the vertical section of the arch to be rectified two years after the bridge had been opened to traffic. Meanwhile contraction of the concrete had taken place to the extent of about $\frac{8}{10000}$ of its length, and this had produced a sag at the crown of about 10 or 12 centimetres (4 or 5 in.) Hydraulic jacks were reinserted in order to effect a remedy, and the two half-arches were separated again without any interruption of traffic over the bridge. As the space between the half-arches was being increased metal sheets were introduced and levels taken, and when the level, according to design as previously established, had been reached, the lining between the two sections of the arch was completed and filled in with concrete ; since then, the shape of the walls has not changed.

By this process, alteration in the shape of an arch may be corrected during or after its construction. In the case of the St. Pierre-du-Vauvray Bridge, the frames were removed before constructing the bracing caissons and the roadway flooring. The expansion of the roadway flooring had been allowed for and an elastic expansion joint provided at both ends of the bridge ; the joint consists of a clear separation of the flooring, each side of the joint resting upon a cross-girder. The two opposite edges of the slit may be represented as a sort of rent ; the free space between which has been partially filled in with a semi-articulated concrete lining.

The bridge has been constructed by Messrs. Limousin et Cie, to the design of M. Freyssinet.

NEW METHOD OF DESIGNING REINFORCED CONCRETE WATER TANKS.

In a paper read at the last Convention of the American Concrete Institute, Mr. W. S. Hewitt advocated a new method for the design of reinforced concrete tanks.

In some preliminary remarks he said the great difference between the circular structure subject to hydraulic pressure and an ordinary structure such as a bridge was that the former was in tension in all parts of the side walls while tension in the latter was only local. To put concrete in even low tension was to invite trouble. Minute cracks invisible to the naked eye or even fine hair cracks were not likely to be serious in ordinary structures, but such cracks in structures subject to water pressure were likely to cause serious trouble.

Shrinkage of concrete was a much more important factor in a structure subject to hydraulic pressure than in an ordinary structure, but that great factor had received but little consideration in existing tanks. In cases where these tanks had been kept wet until filled and were then kept filled, or partially filled, no serious results had followed from shrinkage, but if one examined the history of tanks that had stood for some time before being filled, or had been repeatedly emptied and filled, the result of shrinkage was apparent.

Early tanks of reinforced concrete were designed without consideration of either shrinkage or tension in the concrete. The horizontal hoops of steel were designed to resist hydraulic pressure. The unit stress ranged from 10,000 lb. to 13,500 lb. per sq. in. The thickness of the walls was evidently determined by the experience of the designer. This method of design prevailed until about 1912, and some of the tanks designed during that period were :

Location	Diameter	Height	Year Built.
	Ft.	Ft.	
Attleboro, Mass. . .	50	102	1904
Waltham, Mass. . .	100	37	1906
Manchester, Mass. .	50	72	1909
Westerley, R.I. . .	40	70	1910
Lexington, Mass. . .	30	104·5	1912

No absolute failure was recorded in these tanks. Troubles encountered were cracking and spalling off of the concrete in the side walls and seepage of water through the side walls, resulting in discoloration of the exterior.

In each of these tanks the bottom of the tank was a flat slab, resting on the ground, with the side walls anchored securely to it. This anchorage prevented the expansion of the side walls at the bottom, and the expansion of the side walls above this restraint was excessive. Where the work was not continuous these forces attacked the weak horizontal planes due to construction joints.

The history of these tanks was much alike, and a statement of the behaviour of one might be accepted as applying to all. In the tank at Waltham, Mass., the horizontal reinforcement was designed to take the pressure at a unit stress of 12,000 lb. per sq. in. ; the concrete was 1 : 2 : 4 ; the side walls were 18 in. thick at bottom, and 12 in. thick at top ; the percentage of steel at the base of side walls was approximately 4·23. In March, 1915, the designer of the tank said : " The result has been this. The first year or two there was very little seepage ; some at joints, and a good deal of efflorescence, and some stalactite formation on the outside of the wall. After being in use for a year or two the seepage began to increase considerably, so that when the tank was full a considerable portion of it has been and is quite wet."

At the same date, the designer of the tank at Manchester, Mass., stated : " I have noticed, first, that the greatest amount of seepage and of leaks has occurred on the south and west sides, where the expansion seems to be the most unequal. I have also noticed that, as from time to time the standpipe is lowered entirely and filled again, the successive fillings have produced new points of seepage. At all events, they act a little differently, and are cumulative in their effect. Thus, each time a standpipe is emptied and filled I believe that a slight increase in seepage for a time at least takes place."

In none of the published statements relating to these tanks was there any reference to the effect of shrinkage in the concrete. Because in most cases the greatest amount of seepage occurred on the south exposure of the tank it was inferred that the seepage was due to temperature cracks. But if these cracks were opened by the sun then the greatest seepage would occur when the sun was bright. The cracks were more numerous on the south side of the tank, but seepage was much greater on a dull day or during the night than under the direct rays of the sun. When the water was drawn out of the tank the south side dried out much faster than the north side, with resultant greater shrinkage. If the tank were allowed to remain filled for some time a part of this seepage stopped— regardless of the action of the sun.

The side walls of a tank being thin and elevated well above the ground dried out with great rapidity. One could get a clear idea of the magnitude and importance of the cracks that would appear in a body of reinforced concrete by comparing its elongation with the records made in experiments on reinforced concrete beams. In such experiments, water marks appeared at an elongation of about 0·0001 and cracks became visible soon after the elongation passed 0·00025. Where an analysis showed the combined shrinkage and pressure stresses in a tank would result in elongation exceeding 0·00025 then the resulting cracks would be serious. Such cracks would require the application of elastic waterproofing and such waterproofing was not likely to be permanent. But probably the most serious result of such large elongations would be the disturbance of the bond between rods and concrete.

In the side walls of the Waltham Tank the percentage of steel was approximately 4·23. Take (C) the coefficient of contraction due to shrinkage at 0·0003. Assume the modulus of elasticity for the concrete at 3,000,000 and the modulus for the steel at 30,000,000. Let f_c = unit tension in concrete and f_s = unit compression in steel per sq. in. due to shrinkage :

$$f_c = CE_c \frac{np}{1 + np}$$

$$f_c = 266 \text{ lb.}$$

$$f_s = 6300 \text{ lb.}$$

This would exceed the ultimate tensile strength of the ordinary concrete, and thus the concrete would probably crack from shrinkage alone with this high percentage of steel. Even with much smaller ratio of steel the tensile stress would be high enough so that when water pressure was applied the concrete would be certain to crack, throwing on to the steel the entire stress due to the water pressure. The steel stress would change suddenly from compression of 6300 lb. in the illustration above to a tension of 12,000 and undergo a total change of 18,300 lb. corresponding to a unit elongation of 0·0006. This it was known must result in serious cracks. It should also be noted that this change from the large compression due to shrinkage to the full tension under water pressure might be quite sudden with consequent shock.

Since 1912 there had been several tanks built in which the side walls were entirely free from the bottom. These tanks were provided with a slip joint at the bottom of the wall, which must be water-tight and still permit movement. Where this joint worked as planned this design cut out the horizontal cracks. Some of the most important tanks of this design were as follows :

Location	Diameter	Height	Year Built
	Ft.	Ft.	
Fulton, N. Y. . .	40	100	1913
San Francisco, Cal. .	65	35·83	1913
Kansas City, Mo. . .	40	110	1919

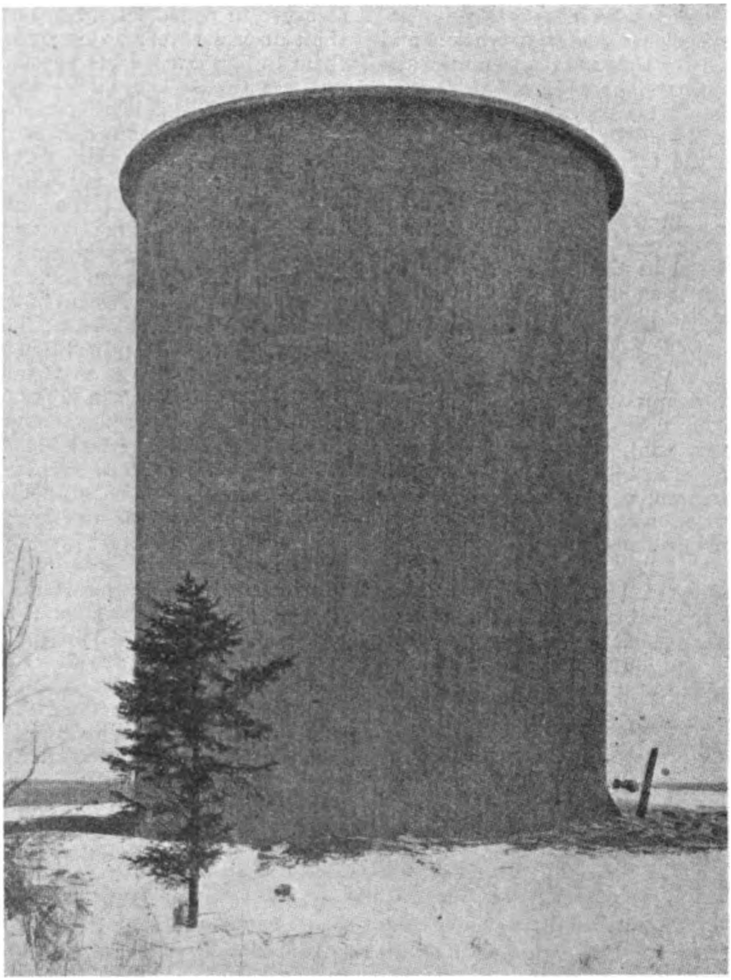
In connection with the San Francisco tank the designers had stated : "The obvious purpose of the sliding joint at the base is to avoid, if possible, the cracks which have usually appeared in the past near the base of the side walls in practically all reinforced concrete tanks of large size. . . . At the time the tank was filled unfortunately no observations were made to ascertain to what extent the joint acted. A close examination at the present time shows hair-line cracks every 8 to 10 ft., extending vertically from a point about 2 or 3 ft. from the base, extending to a height of 8 or 10 ft. No horizontal cracks are apparent. This would indicate a partial action of the joint. The cracks probably failed to extend to the bottom on account of frictional resistance and extended to no greater height on account of the tensile strength of the concrete shell. The use of the sliding joint at the base has as yet developed no objectionable features. It may be questioned as to whether or not in a tank of this height any movement will take place at the joint."

PROPOSED NEW METHOD.

From experience and observation and from a study of the experience and observation of others the author had formed the opinion that a logical reinforced concrete tank should be designed in accordance with the following principles :

(1) Shrinking stresses should be kept at a minimum ; not over 14 of 1 per cent. of steel should be placed in the concrete.
(2) Concrete should not be in tension.
(3) Concrete should not be subjected to heavy shear on horizontal planes.

When these principles of design were observed the ordinary constructor, using ordinary material, with ordinary prudence, might expect the very best of results. In other words, the building of a reinforced concrete water tank became a very simple problem instead of a very difficult one. What had been said of water tanks would apply, of course, to all circular structures subject to hydraulic or fluid pressure, such as oil tanks, pressure pipes, penstocks, etc. His methods of construction could best be outlined by taking an example. At Barnum, Minn., was built in 1922 a tank 20 ft. internal diameter, 32 ft. high, with approximately 75,000 gal. capacity. First, excavations were made to a depth of about 5 ft. and a footing put in for the side walls. Next was built the bottom of the tank, which was a slab 15 in. thick, with a diameter of 20 ft. This slab was reinforced with light radial and circular rods top and bottom, and rested upon the ground with its outer part resting upon the footings already placed for the side walls. Side walls were then constructed 7½ in. thick, with vertical recesses at intervals 15 in. wide and 1½ in. deep. These recesses were for the accommodation of the turnbuckles for adjusting the steel bands. There were three of these turnbuckles in each band. The side walls were built in a sectional form 6 ft. 6 in. high, allowing a vertical run of about 6 ft. each day. The construction joints between the day's work were cleaned and washed before the next day's run was started. Forty-eight ⅝-in. round vertical rods, spaced about 16 in. apart, were placed in the wall. There were also three horizontal bands of ½-in. round rods placed in each day's run about 24 in. apart, as a precautionary measure in construction. The forms for the side walls were adjustable to permit them to be loosened before raising to the new position. The side walls were run in six days. This work was done in late October and November, when temperature ranged from a few degrees below freezing to about fifty degrees. The water used in mixing the concrete was heated, but no other precaution was taken and no heat was applied to the finished work. As soon as the side walls were complete, the work of assembling the adjustable bands began. These bands were simply placed in position and tightened sufficiently to keep them in place. The bands were each in three pieces, the turnbuckles being spaced 20 ft. 4½ in., 20 ft. 4½ in. and 26 ft. 4⅛ in. The turnbuckles were not staggered. The rods were of mild steel, with an elastic limit of about 36,000 lbs. and a modulus of elasticity of about 24,000,000. They were not upset, but were provided with rolled threads. Computations indicated that an initial stress of about 14,500 lbs. per sq. in. was desired in the rods near the bottom, changing to about 15,000 lbs. per sq. in. higher up. The rods were assembled in such a manner that the lever used in tightening the rods worked down. Three men were selected, each weighing about 175 lb., and placed at the turnbuckles. Strain gauge measurements were made at points on one of the rods and the length of the wrench changed until satisfactory readings resulted. It was found that when tightening a rod $\frac{11}{16}$ in. in diameter, a 15 in. wrench in the hands of a man weighing 175 lbs. would give the desired result. This rod was then loosened and the work of adjusting the rods was started at the bottom of the tank. No more readings were taken until all rods had a stress of 14,000 lbs. per sq. in. This rod was No. 18 from the bottom of the tank. Readings taken on rod No. 53 from the bottom showed an average of 14,560 lbs. per sq. in. In adjusting, the rod was tapped with a light hammer at points between the turnbuckles, so as to relieve the brake action and adjust the



REINFORCED CONCRETE TANK WITH OUTSIDE HOOPING, AT BARNUM, MINN.

[20 ft. internal diameter; 32 ft. high; 75,000 gallons capacity.]

rods to the concrete surface with uniform stress. Measurements indicated but slight difference between the stress near the centre of the rod and that near the turnbuckle.

After the rods were adjusted a wire netting covering the entire tank was attached to the rods. The circumference of the outer forms used in moulding the side walls was enlarged to permit the placing of 3 in. of concrete outside the rods and embedding the wire netting. The outer concrete gave a protection to the rods and increased the bearing. Where a " gunite " plant was available a coating of gunite 1¼-in. thick would be preferable to the 3 in. placed as above.

The specifications called for a concrete of one part cement, two parts sand, and four parts gravel or crushed rock. It was expected to use local gravel, but this was later found to be unsuited for the work and crushed rock was used. The sand was washed and very coarse with insufficient fine particles. The rock ranged in size from ¼ in. to 1¼ in. When concreting of the side walls began it was immediately evident that the aggregate did not contain enough fine particles to ensure dense concrete with a ratio of 1 : 2 : 4. However, it was decided to use this ratio for the first day's run in order to learn what difficulties might be expected with porous concrete in this type of construction. After the first day the ratio was changed until the concrete puddled properly. The new ratio was approximately 1 : 2 : 3. After the adjusting of the bands on the lower part of the tank, 9 ft. of water was put in the tank to observe its action on the porous concrete in the lower 6 ft. This concrete, when the forms were removed, showed the rock in many places. When water was put in the tank the lower 6-ft. section sweated to such an extent that the wall was wet on the outside. Above this, where the richer mix was used, only very slight damp spots were observed on possibly 20 per cent. of the surface. None of the construction joints leaked. After allowing the concrete to be thoroughly soaked the water was drawn off and the inside of the tank wall given a brush coat of waterproof cement, and followed by a brush coat of 80 per cent. cement and 20 per cent. waterproof cement. Both coats were put on with paint brushes and but very little left on the surface. After a few days the tank was again filled and found to be absolutely dry, not a single damp spot appearing.

The tank was entirely filled before the outer coat of concrete was placed to permit measurement of the ultimate tension in the rods. This ultimate stress measured 16,500 lbs. per sq. in. Five per cent. of hydrated lime, by bulk, was used in all concrete.

The next day after the tank was completed it was filled to its capacity and left three days for examination. Not the least dampness ever appeared on the outer surface.

The method of design was as follows :

The thickness of the side walls was determined by the compression due to the initial stress placed in the adjustable rods. The initial stress in the bars should always be slightly under the final stress to produce a condition of zero stress in the concrete. Hence, dividing the total hoop tension, due to hydrostatic pressure, by a working unit stress for concrete in compression the minimum thickness was obtained.

In the Barnum tank the pressure in the first foot from the bottom was $62{\cdot}5 \times 32 \times 19 = 20{,}000$ lbs.

Dividing this 20,000 lbs. by 400×12 gave a minimum thickness of a little over 4 in., but that would be too thin for construction purposes. It was also desirable in the Barnum tank to use a small unit, since the work was to be done in cold weather and it would be necessary to place the bands on the concrete when only a few days old. The side walls were therefore made 7½ in. thick except where the turnbuckles were to come, at which points the walls were made 6 in. thick.

The next step was to determine the size and spacing of the rods. Since the rods were to take hydraulic pressure at a working stress of 16,000 lb. per sq. in., $\frac{11}{16}$-in. round rods spaced $3\frac{9}{16}$-in. were required at the bottom of the tank. At the bottom, where the side wall lapped over the bottom slab, slightly closer spacing was desired because the pressure in tightening was exerted on the floor slab. In the Barnum tank $\frac{11}{16}$-in. round rods were placed 3 in. at this point. The rods above the bottom were spaced as required by the pressure, changing the spacing by $\frac{1}{16}$ in. It should be noted that where rods were to be assembled on the finished wall very accurate spacing was possible.

The third step in design was to determine the initial stress to be placed in the rods. That stress was intended to be such as would result in substantially zero stress in the concrete when the tank was filled. The following notation was adopted for the computation of this stress:

Let A_c = Area of concrete (thickness of wall times spacing of rods).
A_s = Area of the rod.
$R = \frac{A_c}{A_s}$
E_s = Modulus of elasticity of the steel.
E_c = Modulus of elasticity of the concrete.
$n = \frac{Es}{E_s}$
S = Final tension stress in steel per sq. in.
y = Initial tension stress in steel per sq. in.
x = Initial compression stress in concrete per sq. in.

When the rods were tightened on the empty tank the total tension in the rods must be resisted by compression in the concrete, or

$$A_c x = A_s y.$$

From this equation they got by inserting R for

$$Rx = y \quad \ldots\ldots\ldots\ldots \quad (1)$$

If the initial stress in the steel was such that when the tank was filled the stress S in the rods would balance the pressure with a resulting stress of zero in the concrete, then when the pressure was released the change in the rod stress of $(S - y)$ would be accompanied by a change in the concrete stress from zero to x. But the change in length of rods and concrete must be the same. Since the change in length was the same, the change in stress in the steel must be to the change of stress in the concrete as the modulus of elasticity of steel was to modulus of elasticity of concrete, or

$$\frac{S - y}{x} = \frac{E_s}{E_c}$$

By inserting n in this equation it reduced to

$$S - y = nx \quad \ldots\ldots\ldots \quad (2)$$

From Equations (1) and (2) we got

$$x = \frac{S}{R + n} \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$y = \frac{RS}{R + n} \quad \ldots\ldots\ldots\ldots \quad (4)$$

Equation (4) gave the initial stress desired, y, in terms of R and S, which were now known and n which must be estimated from the character of the concrete which it was proposed to use.

In the tank under consideration there was an 11/16-in. rod and the spacing was 3 9/16-in. on the wall 7½-in. thick. A_c was then 26·82, A_s equalled 0·3712, S equalled 16,000, E_s was taken at 24,000,000 and E_c estimated at 3,000,000, giving $n = 8$.

That gave 14,400 lb. per sq. in. as the proper initial stress to put in the rods. The initial stress varied from the computed stress but little. The final stress was slightly larger than the computed final stress due to the large value of n in the green concrete.

It might be well to point out here that while n must be estimated in advance of any definite information as to its value as in the design of all other types of reinforced concrete construction, considerable variation could be made in its value without materially affecting the results. For example, in the tank under consideration had n been assumed at double the value above, namely, $n = 16$, and had its true value later been found at 8, the condition of stress instead of being 16,000 lbs. per sq. in. in the steel and zero in the concrete, as assumed in the design, would have been 14,900 lbs. in the steel and a tension of 18 lbs. per sq. in. in the concrete. Thus, it would be seen that even with the large difference assumed the resulting tension in the concrete was only nominal. Should the value of n chosen prove to have been too small it meant the reverse of the above conditions. As it was the purpose to avoid tension in concrete, it was better that the value of n should always be taken too small rather than too large.

The author did not propose, of course, in actual practice to measure the stress in each rod. His experience with tightening the adjustable rods indicated that a rod might be tightened to a predetermined initial stress by adjusting the length of the wrench to the size of the rod and the weight of the man. Since the man always tightened the rod with the wrench working down, and was supposed to put his whole weight on the wrench, very close results might be obtained. Small variations might be expected, but in order to show that even great variations would not defeat the purpose of the design, he had assumed a variation in the initial stress of from 10,000 to 20,000 lbs. per sq. in. as applied to the Barnum tank.

The rods in the tank were $\frac{11}{16}$-in. round for the lower 16 ft. of the tank and $\frac{9}{16}$-in. from that point to the top. The $\frac{11}{16}$-in. rods were spaced from 3$\frac{9}{16}$in. at the bottom to 7 in. at a point 16 ft. from the bottom. The $\frac{9}{16}$-in. rods were spaced 4$\frac{3}{4}$ in. just above this point and were spaced 14 in. at the top. Table I showed the results of tightening the different rods 10,000 lbs. per sq. in. and 20,000 lbs. per sq. in. It also showed results of the value of n at 8 and 15. The m in the table was the stress per sq. in. left in the concrete when the tank was full. The plus sign indicated compression and the minus sign tension.

A study of the table showed that even with extreme carelessness in tightening the rods or with a wide variation in the value of n the resulting conditions were far from serious.

In structures of any magnitude the saving in concrete would be quite material, as the old method called for the side walls to be made thick enough to take the pressure within the elastic limit of the concrete in tension. His method required only sufficient thickness to carry in compression a load slightly less than the hoop tension due to pressure. The problem of waterproofing under the old method was a very serious one. Under his method rich concrete would not require waterproofing and porous concrete could be waterproofed at a small expense.

In the Barnum tank 3$\frac{3}{4}$*d*. per sq. ft. was spent on the waterproofing of the inner surface. The total cost of the 3-in. outer coating, including the wire netting, was 9*d*. per square ft. The assembling and tightening of the adjustable hoops cost about £4 per ton, which was a trifle in excess of the cost of assembling horizontal rods in tanks built under the old method. The most important feature was the production of a logical structure with all material well within the elastic limit. Such a structure should be permanent. Where a tank was built with the stresses in concrete beyond the elastic limit in tension there was not only a serious problem in making such a structure hold water, but there were greater doubts of its permanency.

TABLE I.

Spacing, in.	A_c	A_s	y	x	n–8		n–15	
					S	m	S	m
3$\frac{9}{16}$	26·72	0·3712	20,000	278	22,224	+87	24,170	+113
7	52·5	0·3712	20,000	141	21,128	+36	22,115	+43
10	75	0·2485	20,000	66	20,520	+15	20,990	+17
3$\frac{9}{16}$	26·72	0·3712	10,000	140	11,120	–70	12,100	–54
7	52·5	0·3712	10,000	70	10,560	–38	11,050	–35
10	75	0·2485	10,000	33	10,260	–19	10,495	–18

As to the cost of this mode of construction, he was of the opinion that tanks of considerable size could be built under this method cheaper than under the old method. The fact that it was possible to use steel at a high unit stress saved materially in the weight of the steel. By the use of rolled threads the price per lb. was advanced but a trifle. The total cost of the bands under his method was materially cheaper than under the old method. The assembling of the bands was at least as cheap as under the old method, and the tightening was more than compensated for by the saving in placing concrete in the walls without being bothered by the horizontal hoops.

A logical solution of the peculiar problems that had confronted the builders of concrete structures of this character in the past should open a wide field for the use of concrete. If one examined the skyline of any large city like Chicago wood tanks by tens of thousands would be seen, many of them on concrete supports. The final solution of the small roof tank and the wayside water tank of the railroad would probably be the pre-moulded tank. In his opinion, the ultimate solution of structures subject to hydraulic pressure must be largely by the use of reinforced concrete.

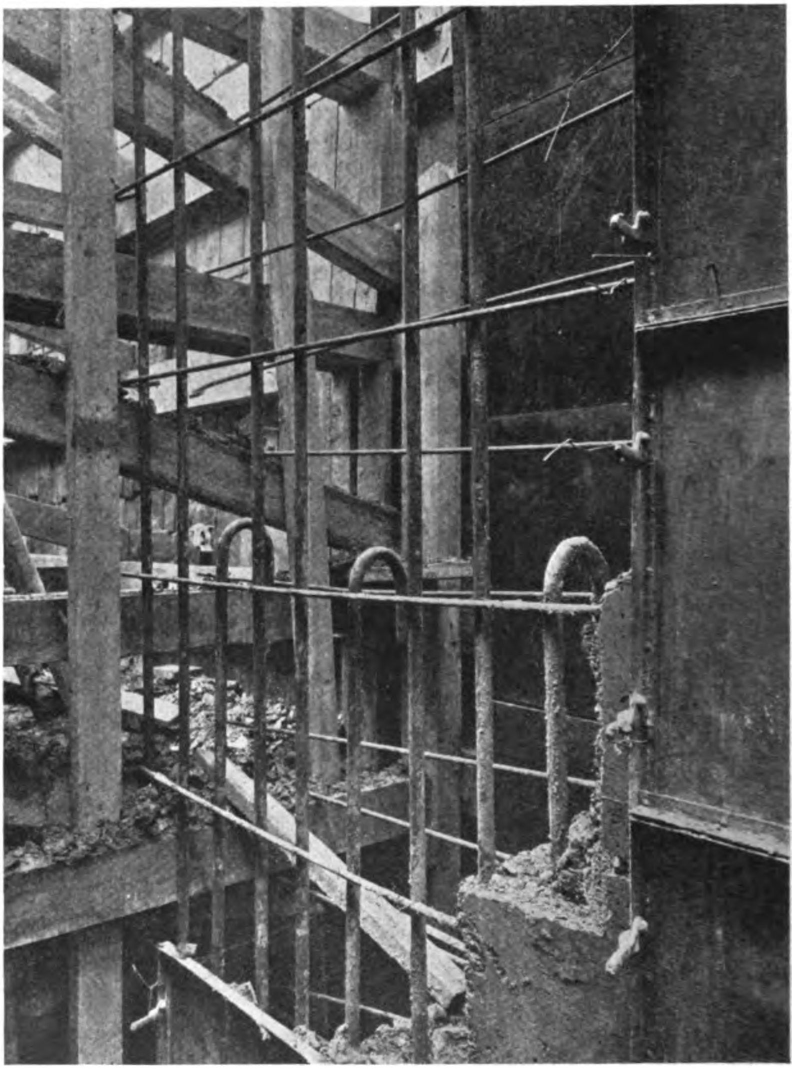


Fig. 3.—REINFORCED CONCRETE RETAINING WALL. (*See p.* 297.)

REINFORCED CONCRETE RETAINING WALL.

WE reproduce herewith some photographs and typical drawings of a reinforced concrete retaining wall which has just been completed around the site for new large dairy premises, to be erected for Messrs. Curtis Brothers & Dumbrill, Limited, at Streatham. Behind the wall is to be laid a reinforced concrete road which will form the inlet and outlet for vehicles which will pass up the incline from the main road, which is at first-floor level at the back of the building and then return at the other side. The wall rises from road level to a height of approximately 20 ft. (the levels changing slightly practically throughout its length), a 3-ft. parapet being provided.

The wall was constructed by first forming a trench in the existing hillside, strutting back the earth on to the front of the trench to enable the construction of the reinforced concrete wall to proceed; this strutting is clearly illustrated in *Fig.* 2. A typical section and elevation showing the reinforcement in the wall are shown in *Fig.* 4, the reinforcement schedule for this portion of the wall being reproduced in *Fig.* 5. The main reinforcement throughout the major portion of the wall consists of large plain round bars at 6-in. centres at the bottom, these bars being stopped off in the manner indicated in the drawing as the height of the wall proceeds and therefore the bending moments in the wall slab diminish. The transverse reinforcement, which acts as distributing bars and as reinforcement to take up shrinkage and temperature stresses, consists of ½-in. bars, 12 in. apart in the front of the wall and 18 in. apart at the back of the wall. The reinforcement in the heel slab is provided by the bars indicated as *h*, which continue up into the wall forming part of the main wall reinforcement; the bars throughout the work are hooked with the standard hook. The reinforcement is seen in position in *Fig.* 2, and more clearly still in *Fig.* 3 which shows a portion of the wall, the concrete in which is about to be continued farther. This photograph also shows clearly the heavy timbering required to hold back the earth pressure during construction. A close inspection of this

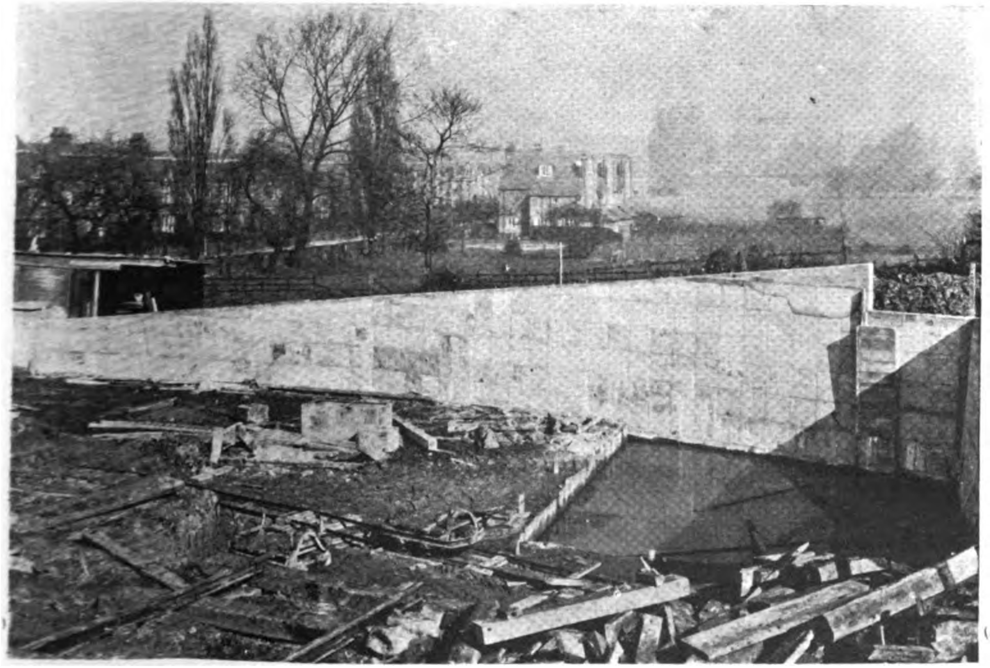


FIG. 1.

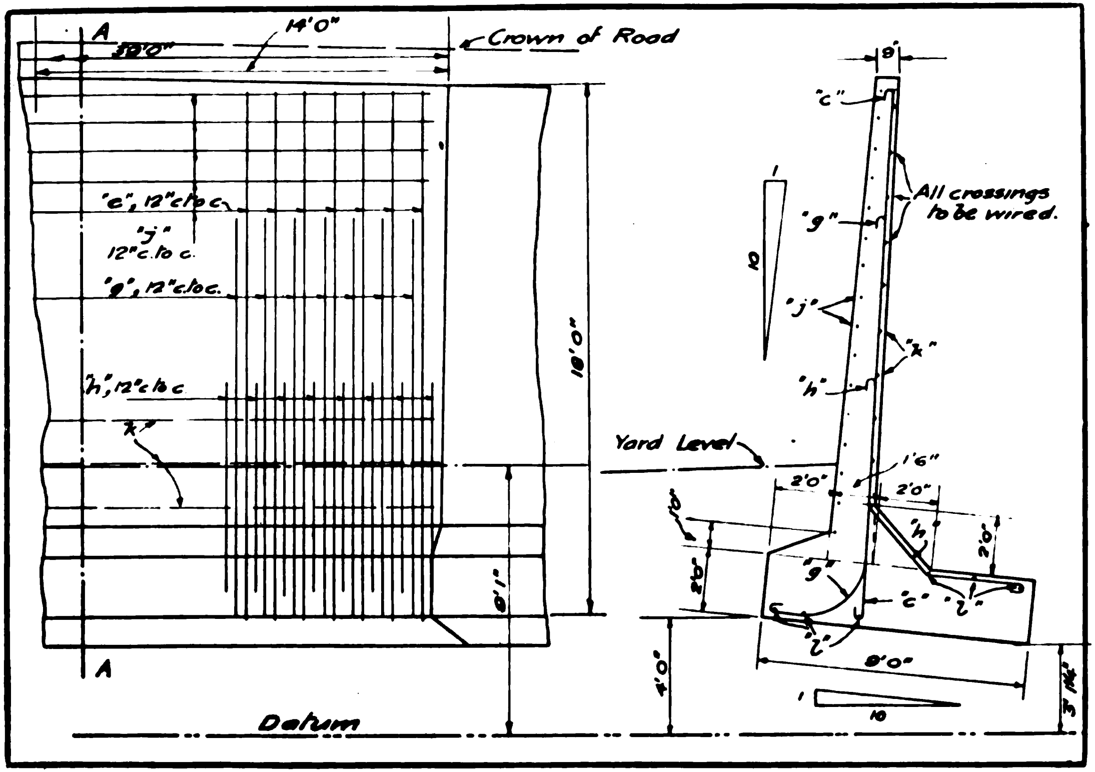

A
14'0"
30'0"
Crown of Road
"e", 12"c.to c.
"j"
12"c.to c.
"g", 12"c.to c.
"h", 12"c.to c.
"k"
18'0"
8'1"
A
Datum
9"
"c"
All crossings to be wired.
"g"
1
10
"j"
"k"
"h"
Yard Level
1'6"
2'0"
2'0"
2'0"
"h"
1'0"
2'0"
"g"
"c"
"l"
"l"
"l"
8'0"
4'0"
3' 1¼"
1
10

Fig. 4.

strutting demonstrated that considerable pressure was already being exerted a short while after the trench had been cut.

Fig. 3 also shows on the right-hand side the "Meta-forms" which were used for the wall formwork; these consist of square metal plates provided with stiffeners and clamping dogs, and they leave the concrete in a much more pleasing form than can be obtained with ordinary timbering. *Fig.* 1 shows the wall exactly as it left the formwork and before any finishing surface was applied; the effect is quite pleasing, and the surface might well be left without incurring the cost of a finishing surface in cases where expense is an important consideration. It is suggested that the makers of these forms might provide a slight projecting ridge which would leave a series of definite lines or grooves on the face of the wall, thus bringing out more clearly the draught-board effect. In *Fig.* 1 will also be noticed the weep holes which have been cast into the wall to take away moisture collecting at the back of it; the projecting portion which will be seen on the wall on the right of *Fig.* 1 is a pier which has been left to support a beam which is to carry an extension of the road to enable lorries to come right into the building which is later to be erected on the site.

In *Fig.* 2 is seen the trench cut into the clay, and in *Fig.* 1 it is seen that the front part has been cut right away after the wall has cured sufficiently to enable the back part to be filled in so that it can carry the load.

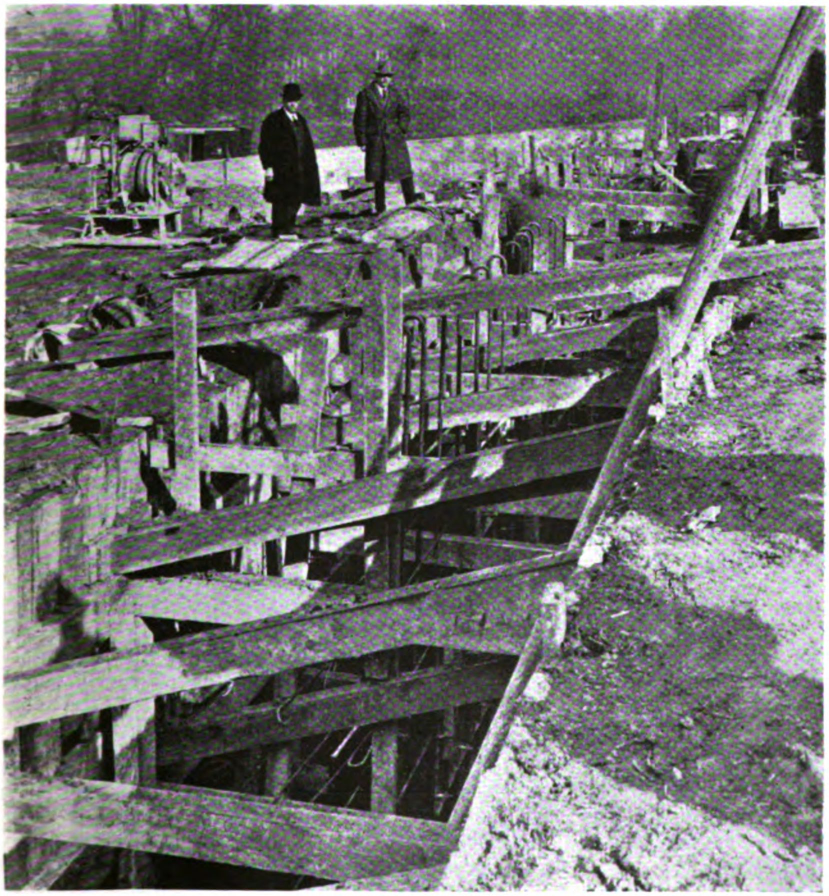


FIG. 2.

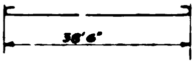
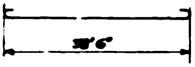
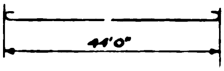
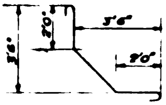
REINFORCEMENT.					
MARK.	No.	SIZE.	LENGTH.	BENDING.	REMARKS.
c	39	1" ϕ	19'6"	As bars "c", Section G.	Vertical in wall stem, bars "c", "g" and "h" alternately.
g	38	do	17'8"	As bars "g", Section G.	Long length vertical in stem.
h	39	do	10'5"	As bars "h", Section G	do.
j	16	½" ϕ	39'4"		Horizontal at front of stem. If shorter bars are used ends must be hooked and bars lapped 1'9"
k	10	do	39'4"		Horizontal in back of stem. Laps as above.
l	6	do	44'10"		Horizontal in base slab. Laps as above
m	16	do	8'6"		Horizontal at corner between Sections H and J.

FIG. 5.

The concrete employed was of a 1 : 2 : 4 mix, the hard aggregate being crushed ballast, and test results taken of cubes during the progress of the work showed that the concrete was well above the usual specification ; in one case the remarkably good result of 4,200 lbs. per sq. in. was obtained after 14 days, although the concrete was made during rather cold weather.

The work was carried out during the winter and under considerable weather difficulties on account of heavy rain and sleet which occurred during the time, but great care was taken adequately to protect the concrete against frost during the period, and the work has been completed in a very successful manner.

The contractors for the work were Messrs. Holliday and Greenwood, Ltd., and the wall was designed by and carried out under the direction of the consulting engineer, Mr. Ewart S. Andrews, B.Sc., A.M. Inst. C.E., M.I.Struct.E., acting in co-operation with the architect, Mr. Ernest Bates, A.R.I.B.A.

PRE-CAST CONCRETE IN MARITIME WORKS.

SOME interesting notes on the use of pre-cast concrete units in the construction of a pier at the Bremerton Navy Yard are given in a recent issue of "Engineering News-Record," to which journal we are indebted for the following account and the accompanying illustrations:

In the construction of pier No. 5 at Bremerton Navy Yard on Puget Sound, where the tide range is about 13 ft., studies were made to find some improved means of meeting the construction problems attendant upon concrete work of this character. Using the result of these studies, the contractors submitted a tender based on comparative studies of plans and estimates covering several different types of construction and arrangement of members. The cost ratio estimated for these several designs was found to be as follows:

3-cyl. bent 30 ft. c. to c. pre-cast	4-cyl. bent 30 ft. c. to c. pre-cast	3-cyl. bent 22½ ft. c. to c. pre-cast
1·00	1·03	1·04
3-cyl. bent 15 ft. c. to c. pre-cast	4-cyl. bent 30 ft. c. to c. monolithic	4-cyl. bent 30 ft. c. to c. structure steel
1·09	1·20	1·27

In accordance with this showing the tender was made on the 3-cyl. bent with the greatest possible use of pre-cast members, and after thorough checking by the Bureau of Yards and Docks, in the course of which some details were changed, the contract was awarded on this design.

The general scheme was to cast the cylinder shells, girder sides, beams and braces, and after these parts had been assembled in place to pour the cores of cylinders and girders as well as the deck slab in such a way as to tie the entire structure rigidly together. The chief problem to be solved in using the pre-cast method was the securing of rigidity and stiffness equal to that existing in a monolithic structure. Adequate stiffness is provided, it is believed, by the connections.

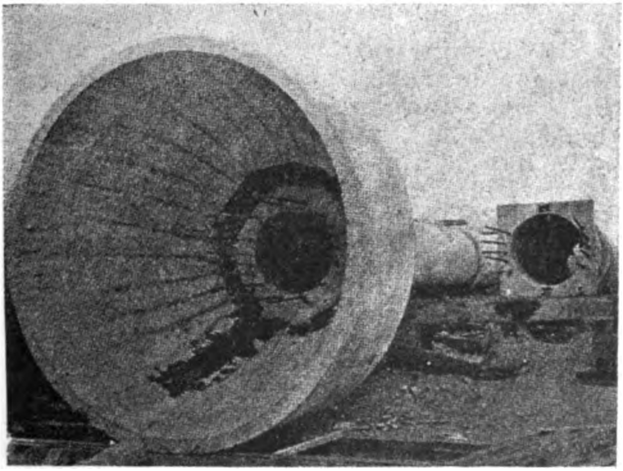
There are several advantages in addition to economy in the pre-cast design over the structure poured in place. Some of these are:

(1) The concrete has opportunity to cure thoroughly and harden before coming into contact with the salt water.

(2) Better concrete is secured because the pouring is done in day shifts irrespective of tides.

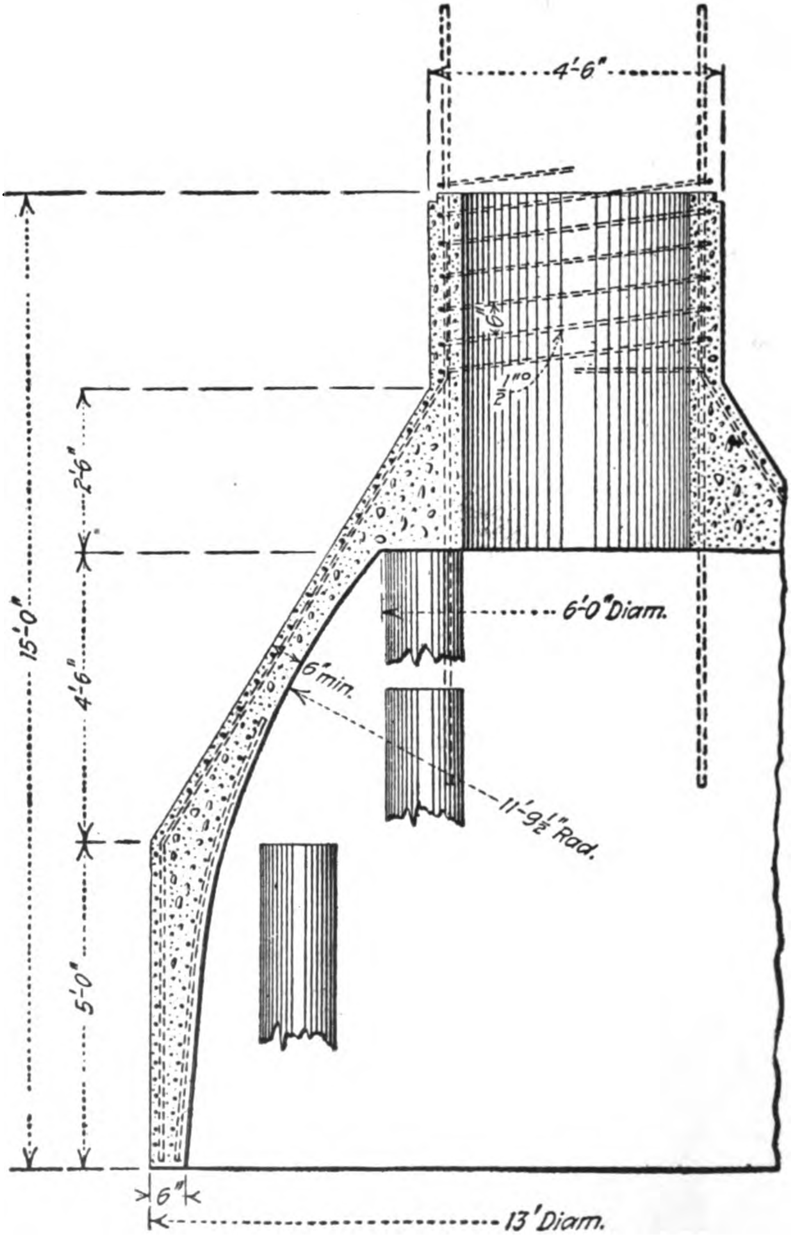
(3) Reinforcing steel is more accurately placed in the forms and easily and positively held in position—an important point in construction in salt water.

(4) The setting of the concrete occurs on firm and unyielding supports, avoiding



PRE-CAST BELL-ENDS READY FOR USE.

The bell-end in the foreground fits over the pile foundations; the square top of the cylinder on the right is for supporting the girders.



DETAIL OF BELL-END OF CYLINDER, SHOWING TEMPORARY SUPPORTING PILE.

the damage that may result from the practically unavoidable settlement of high falsework.

(5) In the pre-cast unit it is possible to cure the concrete properly, thus securing the quality of impermeability so desirable for salt water service.

From the construction point of view there are still other advantages :

(1) The pre-cast unit requires no falsework piling for supporting formwork. (On this particular job piles would have been 100 ft. long and would have had practically no salvage value.)

(2) Greater speed in construction was possible, the actual time on the job being reduced by two months by the pre-cast method.

(3) The cost of formwork and the placing of reinforcing steel was greatly reduced and a much cheaper system of bracing cylinders and holding them in position was possible.

(4) The disadvantage of pouring through slab steel was avoided.

Three 4½-ft. cylinders per bent were used. Incidentally the three-cylinder design with vertical steel rearranged increases the stiffness against side thrust by about 20 per cent.

The main feature in the design is the transverse girder which caps the three cylinders in each bent. The two spans of this girder are each made up of four pre-cast pieces or sides spaced on 3-ft. centres, each 36 ft. long, 12 in. thick with arched soffits varying from 6 to 11 ft. deep, the core or central space between these two sides being later poured monolithic with the slab. The connection between the cylinder top and girder is made by extending the vertical reinforcement from the cylinder shell into the central or poured portion of the girder. In order to support and space the pre-cast girder sides as they were erected, a 16-in. square lattice structural steel dowel was embedded in the cylinder core and extended 7 ft. into the poured portion of the girder. This made a substantial member by which the sides were held in place, and it also added to the strength of the joints between cylinder and girder. Originally it was intended to use a pre-cast concrete dowel for this purpose, but this was later changed to the lattice dowel, which (1) was more easily handled and (2) made it possible to carry the reinforcing and the poured concrete continuously over the joints without any interruption of the continuity of the girder core.

Although the pre-cast sides were designed to carry the major portion of the load, provision was made for transferring the load to the centre by deep grooves on the inside face of the pre-cast sides made by wood strips in the side forms. Further provision for load transfer consisted in interlocking the stirrup hooks between the two sections.

The longitudinal beams were designed as continuous members. For ease in handling it was desirable to have the bent-up rods which extended over the girders as short as possible, and therefore a thorough study was made to determine the point of inflection.

All the pre-cast members were poured in a yard about 1,500 ft. from the pier. A small working wharf was built near the casting yard and connected to it by a standard-gauge track about 350 ft. long and by a narrow-gauge track running parallel with it. The cylinders and bells were cast at the inner terminus of the track and the beams were cast along each side of it. The narrow-gauge track was used exclusively for transporting concrete, while the other track was used by a locomotive crane which handled reinforcing steel and forms and moved the pre-cast beams to the loading wharf. The concrete was all mixed on a floating mixer and delivered by two 1-cu. yd. buckets mounted on a narrow-gauge car.

Both the bell sections and the sections of the cylinder shafts were cast vertically, subsequently being turned to a horizontal position and moved down to the ways, where they were joined and left to cure. The outside forms for the cylinders and bells were made of $\frac{3}{16}$-in. steel plate reinforced with bands and angles. The forms were joined by one vertical joint which was sprung sufficiently to allow easy stripping, this joint being fastened by clips and wedges during pouring. The inside forms for the cylindrical shaft sections were made up with centre posts and hinged radial braces so that they would readily release as the derrick pulled on the centre post.

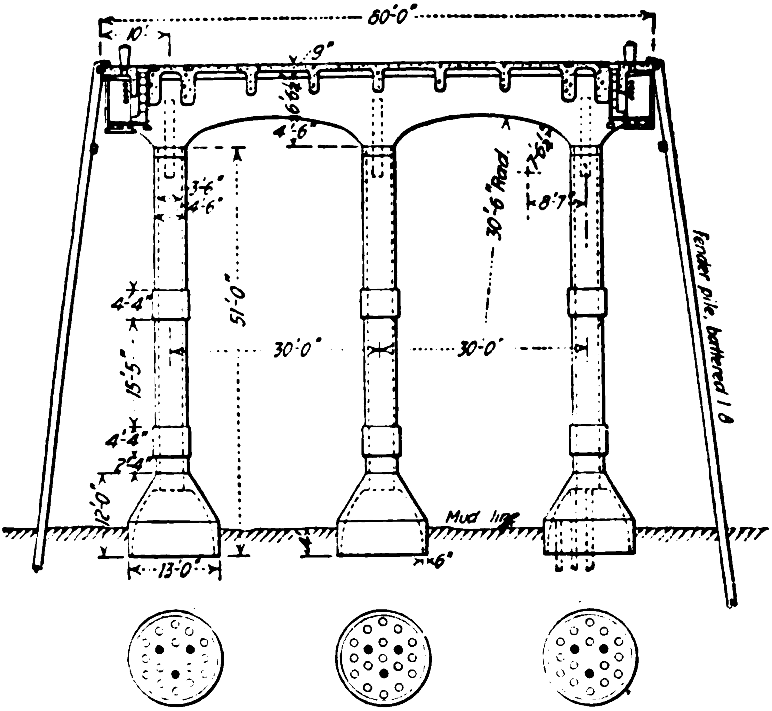
On pier 4, the shape of the inside of the bell was changed from that used on pier 5. The revised section was better adapted to resist stresses resulting from tipping it on its side, as the thickness at the intersection of the cylindrical and conical outer surfaces where the movement is the greatest was increased from 8 to 13 in. The inside forms were made up in one piece with one vertical joint controlled by wedges and turn-buckles. This form was made of rough lumber and covered with sheet iron. Although the contact area was more than 300 sq. ft. these forms stripped very easily in one piece and were used repeatedly after a coat of form oil had been applied. This saved considerable time and expense over the previous method of segmental forms.

The spiral reinforcement for the cylinders was made up and placed in position by the derrick, which then placed the vertical bars inside the spiral. After these were wired to the spiral the forms were placed by a derrick, making this section ready for pouring.

The steel for the bell section was made up on the inside form, and when finished the outside form was lowered into place and fastened to the base. The concrete was settled into position and around the reinforcing steel by vibrating the steel form with pneumatic hammers, and the hardening was accelerated by steaming the day's pours over night, care being taken to keep the temperature about body heat.

The cylinder forms and the outside bell form were removed the day after pouring. The cylinders were tipped by the derrick and rolled down the ways when they were 24 hours old. The bells were tipped when from 45 to 72 hours old; the inside form was then removed and the sections were skidded down the ways into position to be joined to the cylinder sections. Though the bell section weighed about 23 tons and was 13 ft. in diameter, with a shell thickness varying from 6 to 13 in., not a single flexure crack developed in the handling of these pieces.

Each complete cylinder was made up of three pre-cast sections and two poured joints 3 ft. in length. From the contractor's standpoint the design of the joint was a very important matter; it was undesirable to reduce the diameter



Typical Cross Section of Pier.

[The piles shown by full lines are driven to exact grade and support pre-cast cylinder shells.]

of the cylinder core as this would interfere with construction operations. Also, any projection on the inner surface, which was contained in the method suggested by the Navy, added considerably to the cost. Considerable study was therefore given to this detail and a very simple joint was decided upon, which proved satisfactory in all respects. The vertical steel of the pre-cast sections extended 30 diameters beyond the concrete. The sections were lined and placed to make up the correct length of cylinder and in doing this the extending bars meshed together; the regular spiral was then placed around this splice. A second spiral of slightly greater diameter than the outside diameter of the cylinder was placed over eight spacer bars bearing against the pre-cast shells, and the whole was poured with a 3-in. concrete cover over the outer spiral, the poured concrete extending 8 in. beyond the pre-cast sections.

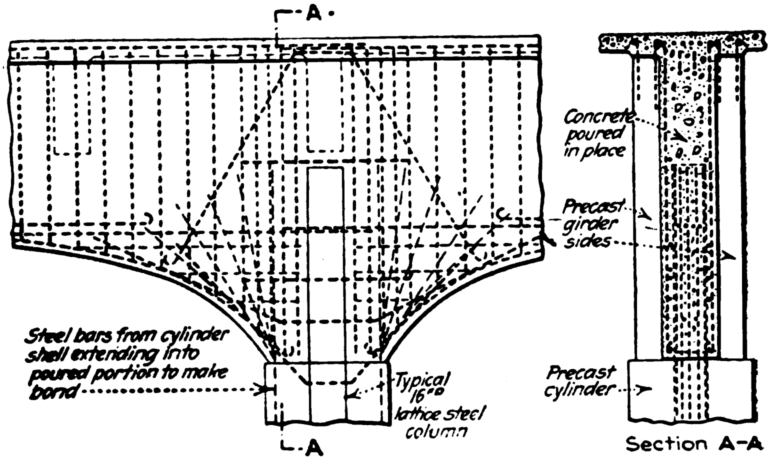
The joined cylinders were cured for 30 days or more and were launched as needed by rolling slowly down the inclined ways, the rigging being such that they were under control at all times; several were, however, allowed to roll freely into the water without damage.

The transverse girder sides were cast vertically on a small platform adjacent to the working wharf, the deck of the platform being constructed to conform to the arched soffit of the girder.

The beams were cast on the ground along both sides of the track. The reinforcing steel was made up on frames at a central yard and was placed in the forms by the locomotive crane. Movable forms were used for both sides of the beams and were removed after 12 hours by the crane. The concrete was poured by crane with buckets. All pre-cast members were cured by sprinkling. Most of the girders were not handled until they were six weeks old, but some of the smaller beams were stored after 14 days, none being placed in the structure, however, until 30 days had elapsed after pouring.

The foundation piles were driven in clusters by a floating driver with a 50-ft. steel follower. The tops of the piles were left from 4 to 9 ft. above the mud line. It was necessary that all piles be accurately driven as the pre-cast cylinder shells were required to fit over the clusters. Three piles in the centre ring were driven to an exact predetermined grade to support the cylinder shell and thereby to bring the tops of the cylinders to the exact grade required for the pre-cast girder sides. All pile clusters were checked by the diver before cylinders were set. Although considerable doubt was expressed regarding the feasibility of this procedure, it was successfully accomplished as planned.

The cylinders, which weighed about 45 tons each, were picked up from the launching ways by a floating shearleg, carried in a vertical position to the site, and lowered over the pile cluster. Little trouble was encountered in placing the cylinders so that they came to bearing on the piles without being thrown off by the


A
Concrete poured in place
Precast girder sides
Steel bars from cylinder shell extending into poured portion to make bond
Typical 16"⌀ lattice steel column
A
Precast cylinder
Section A-A

STEEL FOR BONDING CYLINDER TO GIRDER.

reinforcing steel which extends into the bell core.

The next problem was to hold the tops of the cylinders rigidly in true position. This was accomplished by a horizontal bracing system of cross-braces and walings supported on temporary piles, which were put in position before the cylinders arrived. As the cylinders were lowered into position they were at the same time centered between guides fastened to the outer wale and were held there until the deck was poured. By transferring the weight of the bracing system to a newly set cylinder the temporary piles were released and used again. These piles were used throughout the job and then salvaged.

After the cylinders had been braced and lined, an air lock was placed in the top of a cylinder and the water and mud were forced out of the bottom by compressed air. After the inside was cleaned with fresh water the cylinder core was filled through a ⅓-cu. yd. concrete lock attached to the side of the air lock. When the air lock was removed the lattice dowel was embedded in the fresh concrete, centered and braced.

In order to bring the cylinders to exact grade, and also to make a good bonding surface for the mortar joints, the tops of all cylinders were chipped down about 1 in. The plan was purposely arranged so that none of the cylinders would have to be built up to reach grade, as such construction would make a weak joint. The girders were set at low tide as the cylinder tops were 7 ft. below ordinary high water.

The pre-cast girder sides were bolted to the lattice dowel and to each other to hold them in position and to secure rigidity. The longitudinal beams were also set by the shearleg at high water. The forms for the support of the poured portion of the girder were carried directly to and solely by the cylinders; all deck forms were carried by the pre-cast beams. The deck and girder centres were poured, two bays at a time, by the floating plant. After the slab forms had been removed all construction joints between the pre-cast and poured-in-place concrete were carefully and thoroughly cleaned and joints were filled with gunite. Remarkably rapid progress was made in assembling all pre-cast units and pouring the deck slab. Only 76 calendar days elapsed from the time the first cylinder was set until the last concrete was poured in the deck. The deck slab itself was completed in 48 days.

THE BUILDING EXHIBITION.

After a lapse of two years the Building Trades' Exhibition was held again at Olympia last month. It is probable that some of those specially interested in concrete came away with a feeling that this industry was not so much in evidence as usual, for it has to be admitted that concrete was not so well represented as in the other Building Exhibitions held at Olympia since the war. Many of the large firms actively engaged in concrete construction or in the manufacture of concrete machinery who are usually to be seen at this show were not represented, and the same applies to other trades and industries allied to that of building. No doubt the counter-attraction at Wembley is partly responsible, but so far as the concrete exhibits are concerned one chiefly missed the numerous stands demonstrating new methods of construction which have been a feature of the previous exhibitions. It may be argued that this is no bad thing, as indicating that the extraordinary variety of systems of concrete cottage construction invented and advocated as solutions of the shortage of labour and high costs immediately after the war have been blended into a lesser number incorporating the best features of those which have dropped out, and in this we are inclined to agree. From a large number of different constructional methods there have been evolved a few which are eminently successful, and which are being used at the present time for the erection of many thousands of cottages. The absence of demonstrations of methods of construction at an Exhibition such as this is perhaps the best evidence one could have that there is no necessity for such demonstrations; one never sees an exhibit showing how to build in brick because there is nothing more to be said about it, and although it is certain the last word has not yet been said in concrete cottage construction, it is gratifying to know that it is not now considered necessary to show sections of walling, etc., in order to instruct builders in the methods generally adopted.

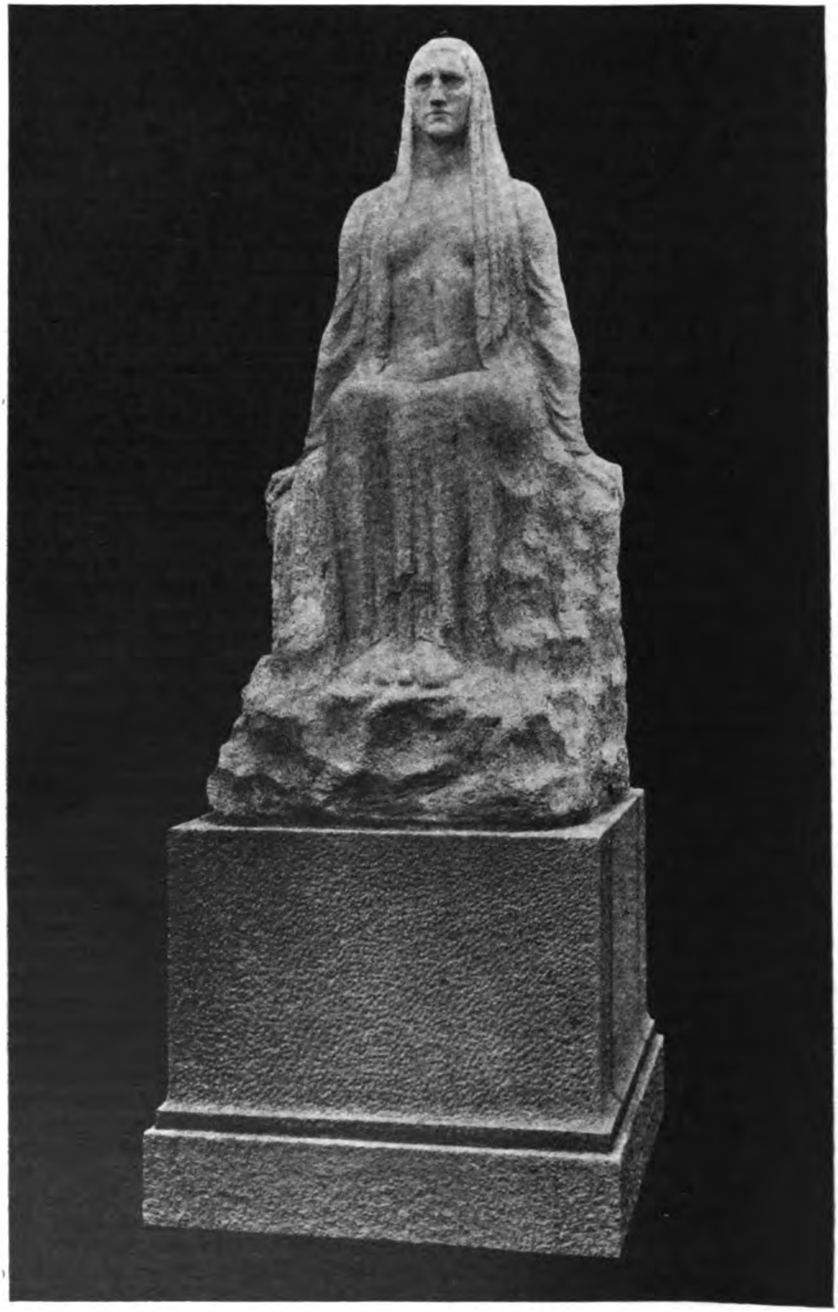
Although construction was not greatly in evidence, considerable attention was given to surface treatments, and some excellent samples of scrubbed surfaces and coloured concrete were to be seen.

Messrs. C. A. Peters, Ltd., of Derby, demonstrated that the "monotonous grey of concrete" one hears so much about is not necessarily a *sine qua non* of the material. On this stand were shown samples of cements in different shades of green, red, yellow, blue, brown, and cream, and also in white and black, from which any colour scheme could be carried out, with the knowledge that the colour would not require renewing at frequent intervals. This firm also showed samples of coloured aggregates suitable for use where a scrubbed finish is required.

One of the most arresting exhibits was a sculptured figure by Mr. F. Doyle Jones, entitled "The Spirit of the Rocks," shown by the Adamite Co., Ltd. The figure is of concrete composed of Cornish granite chippings and white cement, the latter being scrubbed from the surface to expose the aggregate. The result is indistinguishable from granite, and coming from such a well-known sculptor as Mr. Doyle Jones should go a long way in showing what can be accomplished in this material. Some excellent specimens of cast stone made with carefully-selected aggregate were also to be seen on this stand.

On the stand of the Croft Granite Brick and Concrete Co., Ltd., were shown some admirable specimens of well-designed concrete products in the form of garden ornaments, door-hoods and brackets, fireplaces, etc., the clean-cut appearance of which bore testimony to the carefulness with which they had been made. Sewer tubes, paving-flags, kerbs and channels, posts and garden rollers in concrete were also exhibited on this stand.

The increasing use of asbestos-cement goods was shown by the variety of articles made of this material shown on several stands. Although asbestos-cement tiles were most in evidence, there were samples of rainwater pipes, gutters, cisterns, etc., on several stands. "Trafford" asbestos-cement tiles, of which about 1,500,000 sq. ft. are being used for roofing the buildings at the British Empire Exhibition, were shown in many attractive shades by Messrs. Turner Brothers Asbestos Co., Ltd., of Rochdale. These are supplied in one standard size, with a weather surface of 3 ft. 6 in. by 3 ft. 4 in. when fixed to purlins at 3 ft. 6 in.



[*Mr. F. Doyle Jones, Sculptor.*

"THE SPIRIT OF THE ROCKS": A PIECE OF CONCRETE SCULPTURE. (*See p.* 307.)

centres. A new roofing tile in asbestos-cement specially designed for dwelling-houses, and called the "Endurol," was also shown, as also were samples of the well-known "Aegis" asbestos-cement roofing slates and sheets for ceiling-linings, partitions, and similar uses.

Comprehensive selections of roofing felts, sarking and lining felts, damp-courses, etc., were exhibited by Messrs. D. Anderson & Son, Ltd., of Stretford, whose stand included the well-known "Red Hand," "Rok," "Stoniflex," and "Hippo" brands of these goods. Interesting features on this stand were sections demonstrating the construction of a Belfast roof and of the firm's own flat roofing system.

Grey, red and green "Ruberoid" roofings were shown by the Ruberoid Co., Ltd. (296, High Holborn, W.C. 1), in smooth and "slate" finishes, the latter intended for roofings where they may be seen and where a broken surface is an advantage from the point of view of appearance. This firm also exhibited dampcourses, insulating tapes, sarking-felts, etc.

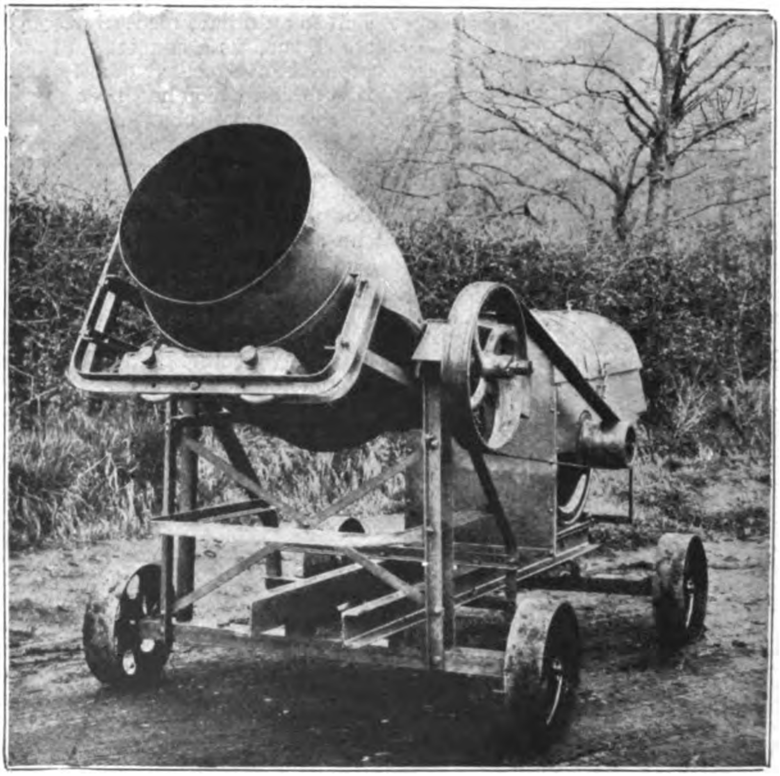
Among the stands displaying machinery for concrete work was that of the Australia Concrete Machinery and Engineering Co., Ltd., of Pordon Road, Brixton, S.W., who exhibited the "Australia" block and slab-making machine, which has an output of 400 plain slabs per day, the "Tonkin" mixer, and a new hoist. Since it was last shown at an exhibition the "Tonkin" mixer has been improved by totally enclosing the engine so that it cannot become clogged with dust or the materials being mixed, and the mixing trough is differently mounted so that a more compact unit is obtained and the tilting-discharge is more convenient.

A simple type of revolving-drum mixer, mounted on a truck with a paraffin engine as a self-contained unit, was shown by Messrs. Drummond Bros., Ltd., of Guildford. This machine has a capacity of 6 to 8 cu. yds. per hour, and the engine is placed so that when the mixer is not working it can be used for driving other plant. The drum is tilted by hand after the materials have been mixed.

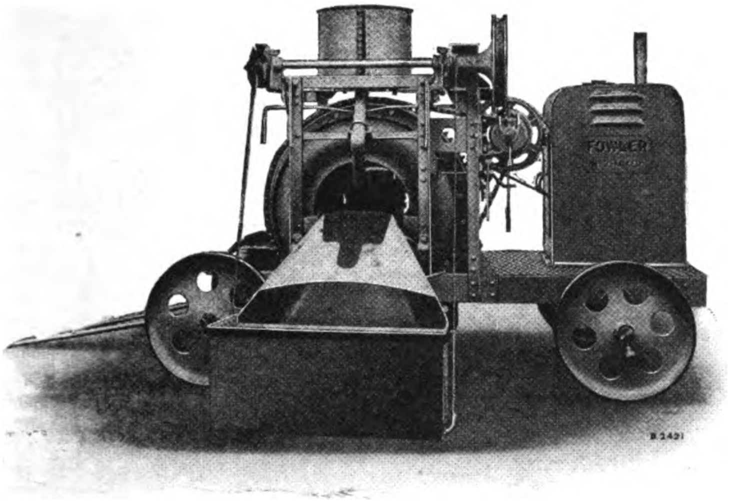
Messrs. John Fowler & Co. (Leeds), Ltd., of Leeds, exhibited two machines of interest to the concrete industry, namely, a mixer and a stone crusher. This mixer is claimed to be the only one in which the drum is made of two different materials in order to reduce weight and prolong its life. A batch is thoroughly mixed in forty minutes. Loading is by batch hopper or power loader, or it can be adapted for a wheelbarrow chute. The plant is mounted on road wheels with a paraffin engine, and is supplied in different sizes from 4 to 56 cu. ft. of mixed materials per batch. In the stone-breaker a new action is introduced which tends to force the materials down into the mouth. The machine is strongly built, and is supplied in three sizes with capacities of 9–16, 12–18, and 18–25 tons per hour respectively, and will produce from 4-in. stone downwards. The illustration on page 311 shows a mixer with a capacity of 10 cu. ft. of unmixed materials and 7 cu. ft. of mixed concrete per batch.

New types of moulding machines and mixers were shown by the Standard Concrete Machine Co., Ltd., of 317, High Holborn, W.C. 1. The moulding machine is specially designed for the production of any type of concrete product, from a slab to an ornate piece of decorative cast stone, such as a sundial, and many such products of excellent quality and attractive design which had been made on the machine were shown. The maximum dimensions of the mould-box are 6 ft. by 3 ft., and by the operation of a hand-wheel these dimensions can be reduced down to 1 in. in each direction, so that the smallest article can be made. The depth of the mould is governed by height of the wooden sides, which may be of practically any height required for the usual run of concrete products, and articles weighing 2 tons may be made. The mould-box is not a fixture on the machine, but is fixed to the metal blocks at the sides and ends according to the size of the product to be made; wood is used for this purpose, a separate piece for each side and each end. The blocks are then closed towards one another by the operation of the handles and the sides and ends of the mould are thus closed together until the corners meet. A pallet is placed in the bottom, the blocking pieces necessary for moulding the product placed in position, and the concrete filled in and tamped and struck off. After the article has been made it is released from the mould by a turn of the hand-wheel at the end of the main shaft, which simultaneously withdraws the mould from all four sides. The pallet is then raised by turning a handle, and the article removed for curing. The distinctive features of this machine are: (1) The mould-box is withdrawn from the product and not the product from the mould-box, which enables a plain product or one moulded on all four sides to be turned out with equal facility. (2) The lifting of the product out of the mould-box for carrying away is effected by a simple geared device arranged so that one man can comfortably raise a product or products having a total weight of 1 ton. The machine is so designed that two men operating this lifting device simultaneously can raise the maximum weight of 2 tons. This lifting device also eliminates jarring or risk of damage to the finished product. (3) The change-over from one required run of products to another is simple and can be accomplished in a few minutes without the removal or addition of spare parts other than the insertion of the four sections of a different mould-box. Having set the machine for products of any specified dimensions, no further adjustment is required during the entire run, nor are any loose packing pieces or moulding strips required. (4) Adequate protection is provided for all working parts to prevent excessive wear through the introduction of gritty substances into such parts.

An open-trough type of mixer was also shown on this stand, in which the materials are mixed by blades mounted on an axle; they are continually turned from one end of the trough to the other and back again. An interesting method of encasing steel stanchions with concrete was a further exhibit. In this system thin square concrete slabs (a little wider than the stanchion to be encased) are placed in position around the stanchion and held in position by tongues and grooves cast in them when made. These small slabs are used as shuttering and concrete is



THE "WILLING WORKER" CONCRETE MIXER. (*See p.* 309.)



THE "FOWLER" CONCRETE MIXER. (*See p.* 309.)

poured between them and the steelwork, thus avoiding the necessity for encasing the steelwork in timber shuttering which has to be removed afterwards.

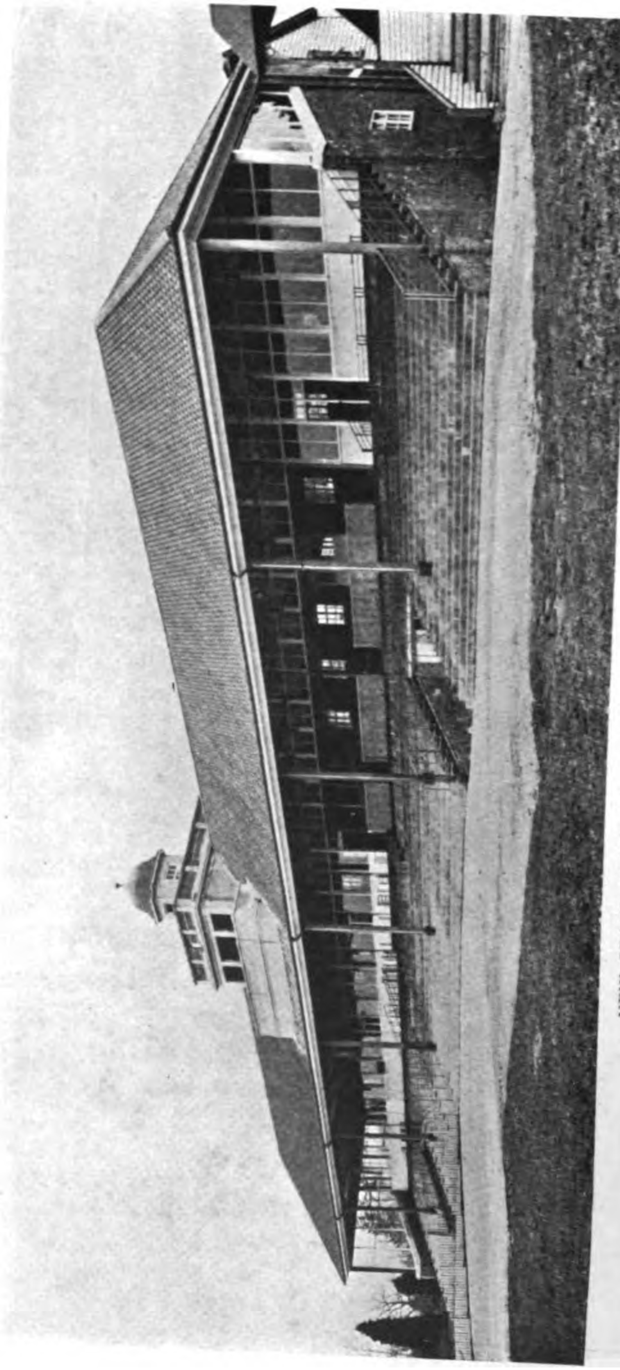
Comprehensive ranges of different types of reinforcement were demonstrated by the Expanded Metal Co., Ltd., of York Mansion, Petty France, S.W. 1, and Messrs. Johnson's Reinforced Concrete Engineering Co., Ltd., of Manchester.

Among the stands on which waterproofing materials were shown was that of Messrs. Kerner-Greenwood & Co., Ltd., (King's Lynn) where the uses of "Pudlo" for waterproofing concrete and brick were demonstrated.

"Metaform" metal shuttering, which is now being extensively used for the construction of concrete walling, was demonstrated on the stand of Messrs. A. A. Byrd & Co., of 11, Queen Victoria Street, E.C. 4. With the use of these standardised forms any shape or size of wall may be built *in situ*, and the expense of cutting and renewing timber for different jobs avoided.

Another simple method of forming *in situ* concrete walls was demonstrated by the Climbing Steel Shuttering Co., of 515, Queen's Road, Sheffield. This shuttering consists of light bolstered galvanised steel plates. Only one row of these is required to build a wall any thickness and any height. The inside and outside shutters are held apart—the thickness of the wall—by means of wires which pass through holes pierced in the upper and lower edges of the shutters. When the concrete has been filled in and has stiffened, the lower wires are cut and the plates are turned up from the bottom, the top wires acting as hinges. The plates have a face both sides, so that immediately they are turned up and wired they are ready for the next charge of concrete; and so the plates revolve to the top of the wall.

The handy and useful machines supplied by Mr. W. Kennedy, of West Drayton, for cold bending reinforcement rods up to 1½ in. diameter were exhibited in several types. These machines embody several improvements.



NEW GRAND STAND AT LINGFIELD PARK RACE COURSE. (*See p.* 313.)

NEW GRAND STAND AT LINGFIELD PARK RACE COURSE.

THIS new stand, now approaching completion, has been erected practically on the site of the small timber grand stand it has replaced.

It has been built to the design of Messrs. Brierley & Rutherford, the architects to the Jockey Club, who have been responsible for a number of new grand stands during the past few years. The reinforced concrete designs and calculations were made in conjunction with The Expanded Metal Company, Limited, who supplied the whole of the reinforcing steel used in the construction. The principal contractors were Messrs. John Laing & Son, Ltd., of London, Carlisle, and Liverpool, who have been responsible for the carrying out of the whole of the work.

The completed stand is one of the most important works of the kind carried out in this country and a high standard has been set up to meet the comfort of members of race courses.

The total length of the stand is 232 ft. 6 in.; the extreme depth from front to back is 44 ft., and the height from ground level to the top step is 16 ft. The stand is capable of accommodating nearly 4,000 spectators.

The stand proper is a steel-frame structure. The whole of the steelwork below the stand is encased in concrete and the steps are constructed of concrete reinforced by heavy-gauge expanded metal.

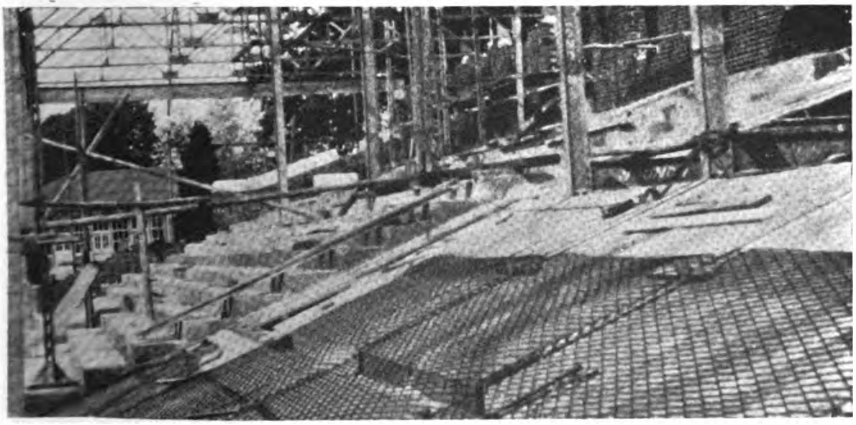
The soffit of the stand is carried through as a continuous sloping ceiling and does not show the risers and treads. This necessitated the shuttering being carefully constructed to ensure the correct thickness of concrete at the bottom of each riser. The expanded metal goes through continuously from steel joist to steel joist, which run longitudinally and transversely throughout the stand.

Practically the whole of the weight of the stand is carried by the steel stanchions and steel frame work and brick piers; and the back wall is carried up in brick quite independently of the steel and concrete construction.

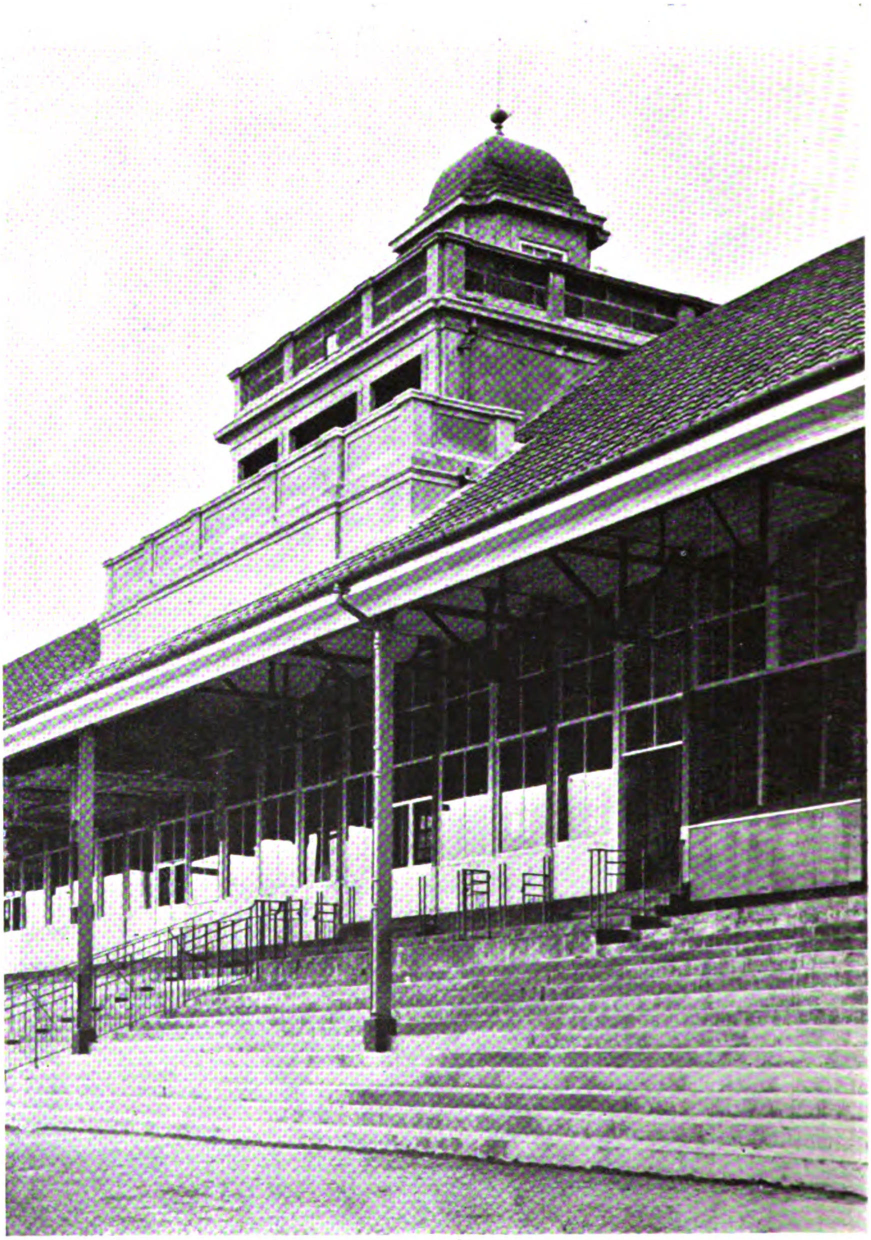
The whole of the concrete of the treads and risers is covered with pure genuine Seyssel asphalte to a thickness of ¾ in.

The underneath portion of the stand, which is fitted out with every consideration for comfort, is devoted to extensive lavatories and cloak rooms for men and women and large refreshment saloons. Every care has been taken in the design to ensure as much light as possible, as the natural means of lighting only comes from one side; this necessitated windows of exceptional size.

There are three staircases at the rear of the stand, each contained in a separate



NEW GRAND STAND AT LINGFIELD PARK RACE COURSE: DURING CONSTRUCTION.



NEW GRAND STAND AT LINGFIELD PARK RACE COURSE.

wing. The north wing contains the staircase leading to the Club. The centre wing, which is a three-story block, contains the stairs leading to the private luncheon room, service rooms, retiring rooms and also the centre portion of the stand, and above this to the balcony surmounted by a domed turret, again in reinforced concrete construction, which is the central feature. The centre wing has also a basement containing boilers for central heating and hot-water service supply.

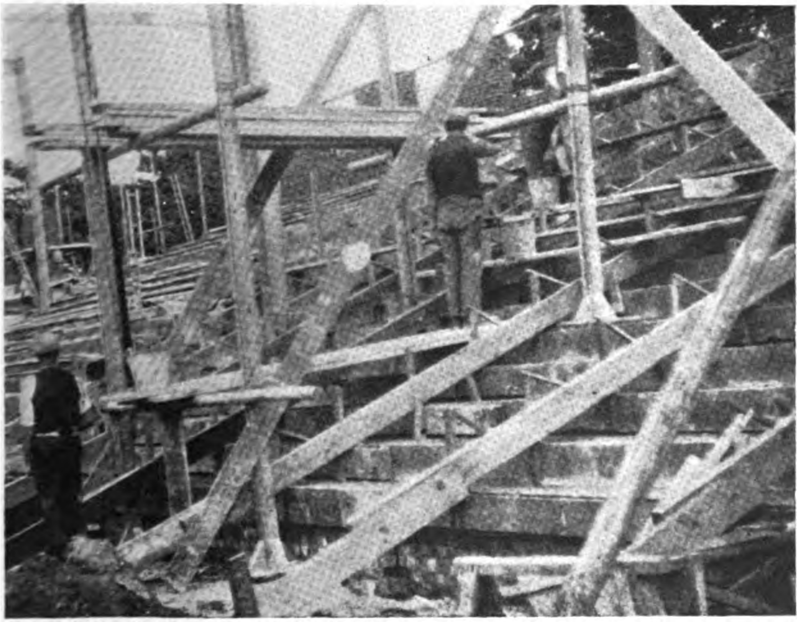
The south wing contains the stairs to Tattersalls entrance to the stand, which is practically a replica of the north wing.

The turret in the centre is reached by the stairs in the private block; the height of the dome is 55 ft. from ground level. From the balcony, which is above the roof of the stand, magnificent views of the surrounding country are obtained, and the greater portion of the Course is within the vision of the spectators who view the racing from this eminence. The balcony and the dome which surmounts it are built up in reinforced concrete on steel stanchions and joists. Some of the mouldings are excellent examples of concrete cast *in situ*. The floor of the balcony and the dome are covered with pure genuine Seyssel asphalte.

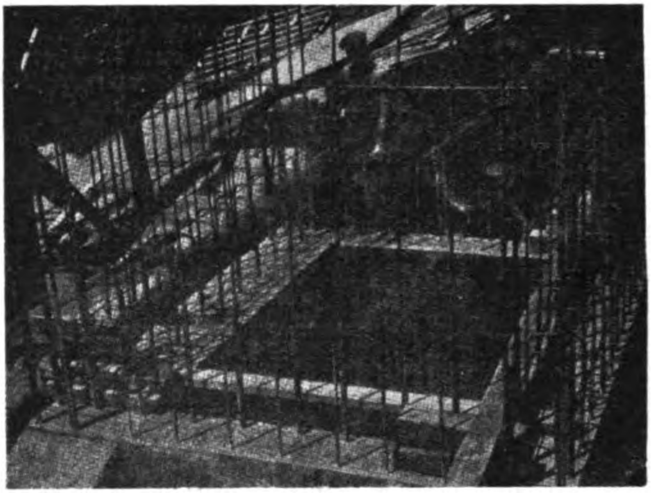
The roof is supported by steel stanchions and steel trusses, and is covered with the old-fashioned Yorkshire pantiles which figure in many of the buildings associated with the name of the Architects.

A large portion of the stand is enclosed by a screen glazed with large panes of plate glass. This portion of the stand is heated in winter months as so many of the meetings at this Course are held in winter. The whole of the under-portion of the stand and luncheon and retiring rooms is also centrally heated, the object of the architects having been to make the stand as much as possible like a well-appointed hotel.

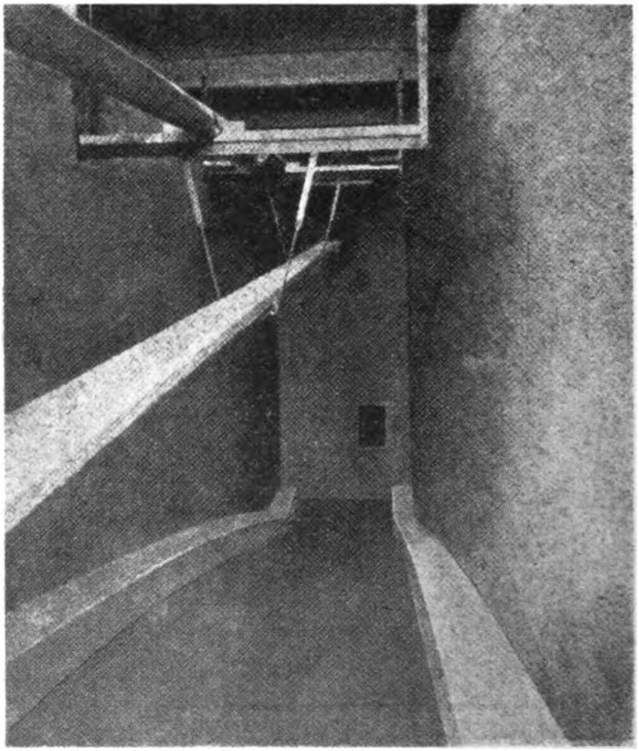
The following specialists were engaged on the work: Steelwork: Messrs. Redpath, Brown & Co., Ltd. Heating: Messrs. Rosser & Russell, Ltd. The whole of the asphalte was executed in pure genuine Seyssel asphalte by Messrs. Thomas Faldo & Co., Ltd., of Windsor House, Kingsway, W.C.2, who have also carried out similar work at the Jockey Club Stand at Newmarket and the new stand at Gosforth Park, Newcastle.



NEW GRAND STAND AT LINGFIELD PARK RACE COURSE: DURING CONSTRUCTION.



HOLLOW PIER DURING CONSTRUCTION.



VIEW WITHIN THE ARCH SLAB AND SPANDREL WALLS, SHOWING METHOD OF CARRYING MAINS AND CONDUITS.

REINFORCED CONCRETE BRIDGE AT YORK, ONTARIO.

ECONOMICAL TYPE OF CONCRETE BRIDGE.

THE reinforced concrete bridge illustrated herewith, situated at York, Ontario, has an overall length of 672 ft., and was built at a cost of £20,000.

In a description of this work, the "Canadian Contract Record" states :—

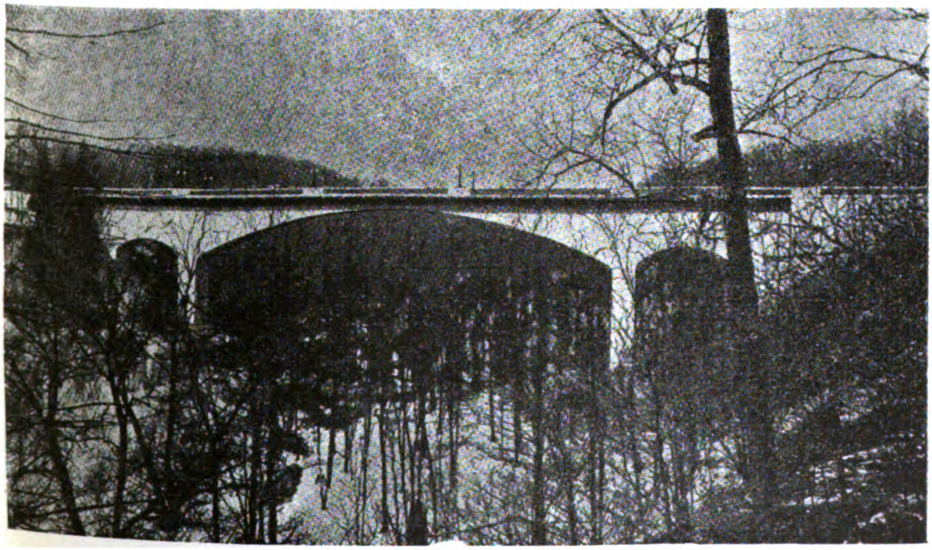
The fact that a reinforced concrete bridge, 672 ft. in length overall and with a main arch of 200 ft. span, can be erected complete for £20,000, is worthy of considerable attention. That the bridge was completed at a cost extremely low in proportion to the size is due to the special features of design that were incorporated in it by the designer of the structure, Mr. F. G. Engholm, of Toronto. This special design, which involved very flat arches with solid spandrel walls, hollow piers and abutments, heavy reinforcing rods and electric welding of the steel, was not only economical in itself but gave rise to inexpensive construction methods. For example, the centering was very light and simple. While only 2,072 cu. yds of concrete were involved in the whole structure, including piers and abutments, and only 140 cu. yds in the arch slab, it is the disposition of this comparatively small amount of concrete and the careful detailing of the reinforcement that made the structure sound and contributed to the low cost of its construction.

The bridge comprises three arches, the main arch having a clear span of 200 ft. and the secondary arches spans of 40 ft. each. It was necessary to have the centre span of this width on account of a right-of-way along the bottom of the ravine. The height above the bottom of the ravine is 88 ft.

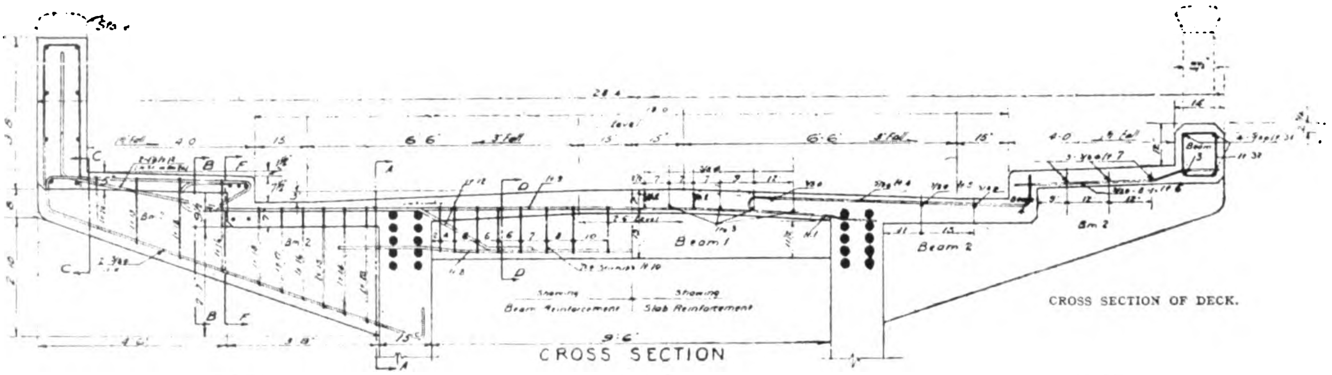
The roadway of the bridge is 18 ft. wide between kerbs, and with the two 4-ft. sidewalks the total width is 28 ft. 4 in.

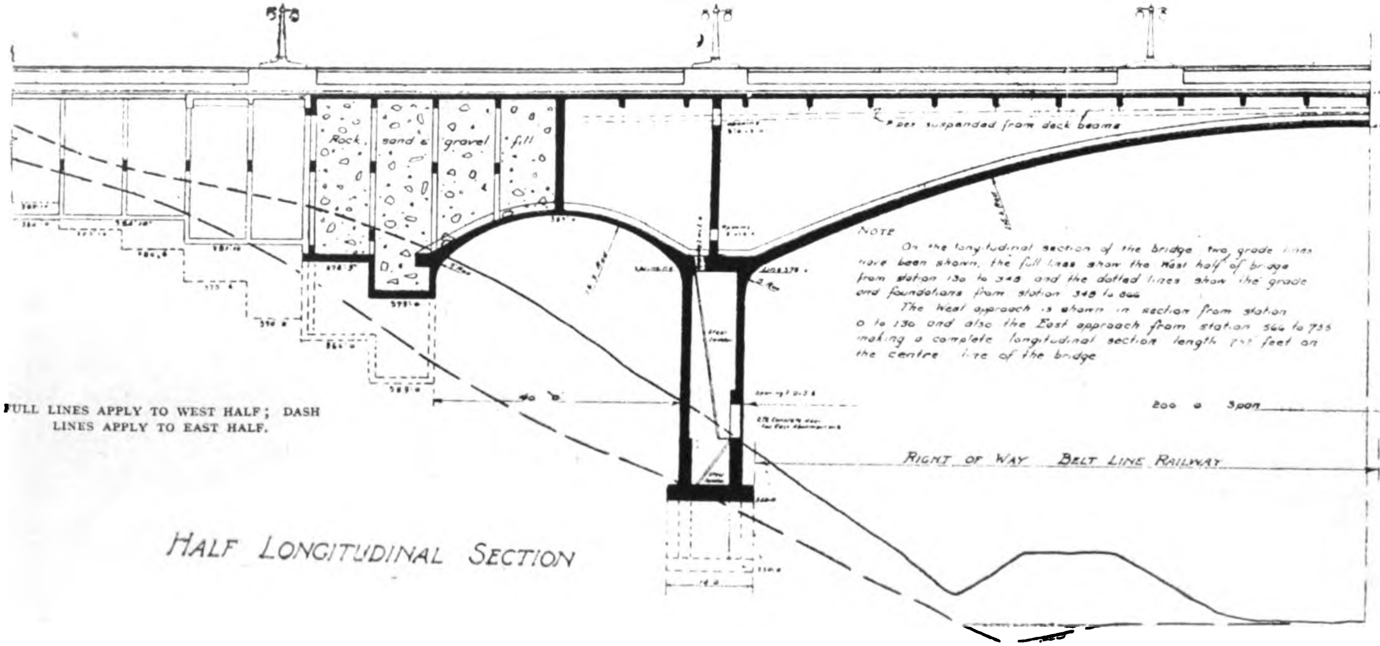
The arches are formed of two solid spandrel walls and an arch slab, carrying a concrete deck on transverse beams, the overhanging part of the road slab, the sidewalks and parapet being carried on beams cantilevered from the arch ribs. Cross spandrel walls are incorporated over the piers and at the crowns of the secondary arches. The arch contours are very flat, the radii of the main and secondary arches being 215 ft. 4 in. and 26 ft. 9 in. respectively. The rise of the main arch is only 24 ft. 8 in., and of the secondary arches 9 ft., while the ribs are spaced 9 ft. 6 in. apart.

At the crown, the arch slabs are only 9 in. thick, and at the springing 21 in. in the case of main arch and 27 in. in the case of the secondary arches. The arch ribs are 15 in. thick. The main reinforcement of the ribs consists of



REINFORCED CONCRETE BRIDGE AT YORK, ONTARIO.




HALF LONGITUDINAL SECTION
Rock, sand & gravel fill
Pier suspended from deck beams
200 0 Span
40 0
14 0
RIGHT OF WAY BELT LINE RAILWAY

NOTE

On the longitudinal section of the bridge two grade lines have been shown, the full lines show the West half of bridge from station 130 to 348 and the dotted lines show the grade and foundations from station 348 to 566

The West approach is shown in section from station 0 to 130 and also the East approach from station 566 to 735 making a complete longitudinal section length [illegible] feet on the centre line of the bridge

FULL LINES APPLY TO WEST HALF; DASH LINES APPLY TO EAST HALF.

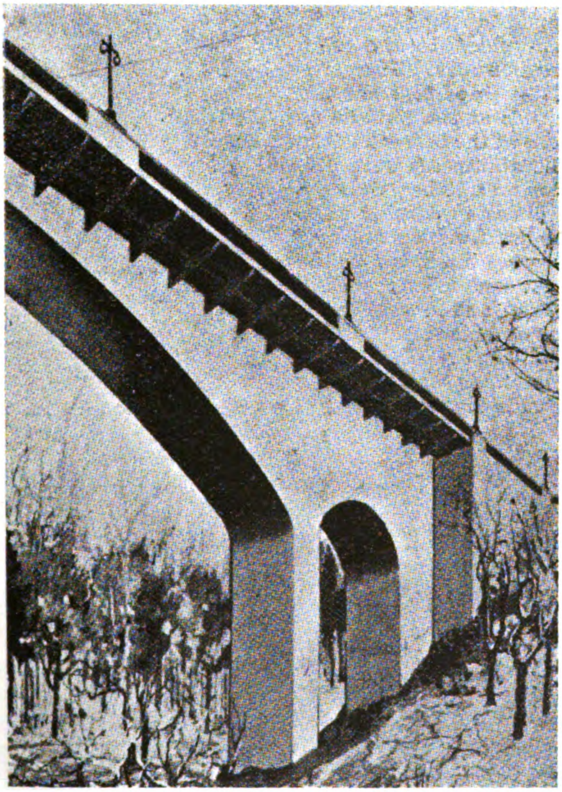
REINFORCED CONCRETE BRIDGE AT YORK, ONTARIO.

fourteen 2½ in. rods maximum, diminishing to three at the centre of the structure. The average weight of the reinforcement per cu. yd. of concrete works out at 184 lbs. All of this steel was electrically welded together after being placed.

The arches are carried on hollow, thin walled, reinforced piers and abutments resting on firm clay. The main piers are rectangular in section, 12 ft. by 10 ft. in outside dimensions, the walls being 15 in. thick, carried on spread footings which are 2 ft. 6 in. slabs, 14 ft. by 36 ft. in area, with two vertical ribs 2 ft. thick and 7 ft. 6 in. high. The footings, ribs and walls are all reinforced. The abutments are also hollow with thin walls reinforced and tied with cross beams. They are filled with rock, sand and gravel up to the 15-in. cross-spandrel wall at the crown of the arch.

In the west pier is incorporated a 2 ft. by 5 ft. 6 in. opening, closed by a 2½-in. concrete door, giving access by means of steel ladders to the interior of the structure for the purpose of examining the pipes and conduits which are suspended from the deck beams.

In constructing the bridge, the contractors framed the arch centering according to standard trestle practice, erecting the bents in 14-ft. lifts. All the timbers in the trestle, including batter posts, plumb posts and caps, were 6 by 6's. The whole was carried on oak mud sills. This is very light centering, considering the span and height, but it was thought that all the weight that would be borne by the trestle would be the soffit of the arch, it being considered that the electrically-welded steel combined with the concrete poured would relieve the trestle of any further load. This surmise was amply borne out in practice. The maximum deformation of the trestle was $\frac{1}{10}$ of an inch vertical deflection, indicating



Reinforced Concrete Bridge at York, Ontario.

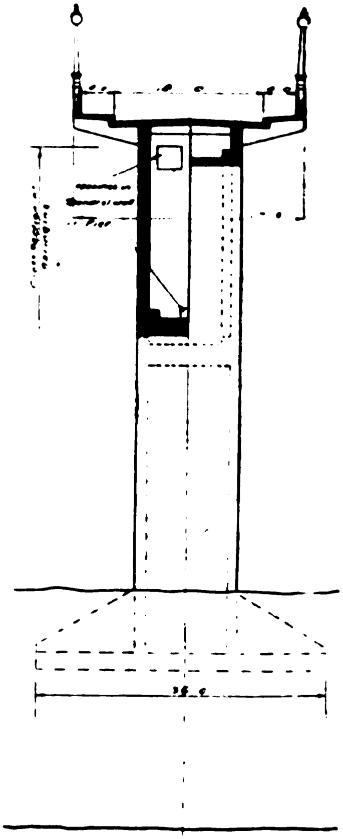
only the timber taking up its bearing over a height of 88 ft.

In proportioning the falsework the concrete was considered a liquid weighing 180 lbs. per cu. ft. for vertical loading and 120 lbs. per cu. ft. for horizontal loading. A working platform was provided and a means of adjustment was incorporated at this platform level to take up any deflection that might have occurred during the operation of pouring the concrete. A careful check was maintained on the action of the centering during the time it was being loaded, but measurements showed an insignificant settlement.

The average pour was 30 to 40 cu. yds. per day, although a maximum of 156 yds. was attained when pouring the arch slab. The arch slab was poured in one continuous run. The concrete was mixed in the proportion of 27 cu. ft. of ¾-in. coarse aggregate to 18 cu. ft. of fine aggregate to 700 lbs. of cement.

The main reinforcement of the arch ribs, consisting of 2½-in. diameter rods, was butt welded, and the diagonal tension members were lap-welded to the main tension and compression rods. The vertical stirrups were lap-welded together and welded to certain rods at the top and to the compression rods at the bottom. The vertical rods in the abutments were also welded to certain top rods. The rods in the ties at the abutments and retaining walls were welded to the main vertical steel.

All butt welds were built up to be approximately 25 per cent. in excess of the original area of the rod, and the welding of the main rods was sufficient to develop the full strength of the rod. The welding of all other intersections was sufficient properly to secure rods in their positions.


Cross Section at Springing
(lower part of arch only)
Cross Section Centre of Span

Reinforced Concrete Bridge at York, Ontario.

QUESTIONS AND ANSWERS RELATING TO REINFORCED CONCRETE.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.*—Ed.**

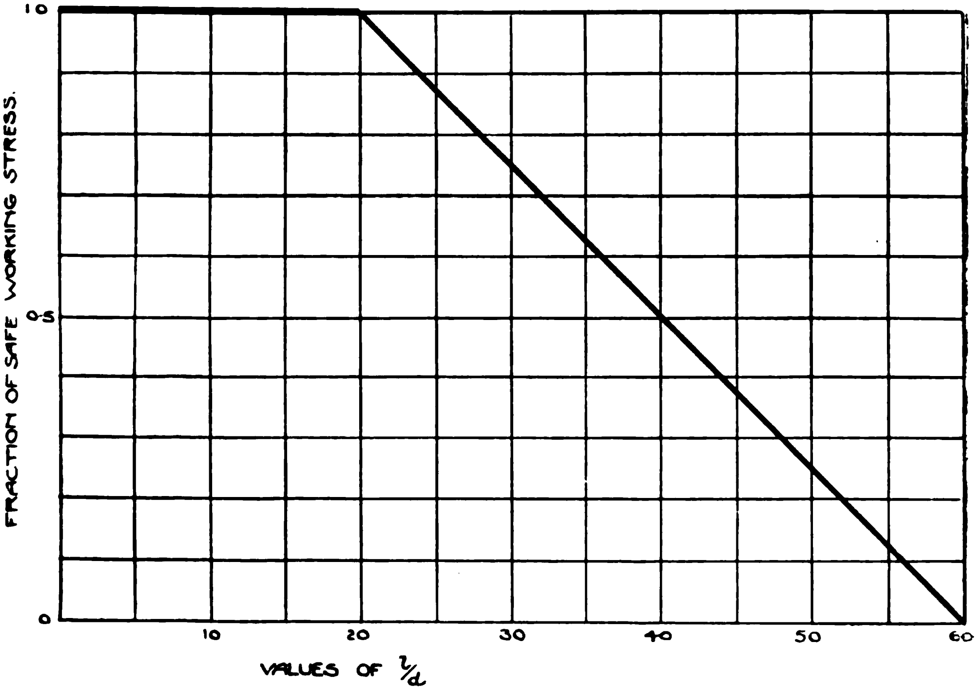
REINFORCED CONCRETE COLUMNS.

Question.—I would be glad if you would let me know if it would be a safe and good standard practice to design long reinforced concrete columns by the Gordon formula as given in some text books?—T. P.

Answer.—We prefer the formula which gives the straight line law, as shown on the sketch below.

REINFORCEMENT FOR CONCRETE ROADS.

Question.—I am interested in the construction of concrete roads, and am at present trying to get information on the amount of steel that should be put into roads and other such structures made in the Tropics to counteract the contraction of concrete when setting, and subsequent movement under the temperature conditions of the Tropics. From various sources I have obtained figures varying from 20 lbs. weight to 50 lbs. weight per 100 sq. ft. super for a 6-in. or a 9-in. thick concrete bed. In this country reference books on engineering are few



WORKING STRESSES FOR LONG COLUMNS.

[Reinforced Concrete Columns. (*See question above.*)

and far between. Hence there is a great difficulty in obtaining reliable up-to-date information. A structure that I have in mind is the floor of a reinforced concrete reservoir on an extremely good foundation, the floor being 9 in. thick. The difficulty I foresee is in avoiding cracks due to contraction. To avoid these cracks steel should presumably be placed with about 2 in. of cover on the top of the concrete; but what weight of steel is necessary?—E.R.

Answer.—Counteracting the contraction of concrete when setting and subsequent movement under the temperature conditions of the Tropics can only to a slight extent be reduced by reinforcement, and therefore it is difficult to give a figure for the reinforcement based on this point of view. But roughly speaking, and with the rather inadequate information in the question, it may be said that $\frac{3}{8}$-in. rods at 6-in. centres in both directions top and bottom for a 6-in. slab, and correspondingly more reinforcement for a 9-in. slab, is the best that can be done by reinforcement. It is best that the reinforcement should be symmetrically disposed, i.e. equally top and bottom, and not, as is suggested, near the top only; because in the latter case shrinkage would produce a tendency to bend, as it would be resisted at the top of the slab but not at the bottom. It is much more effective in preventing cracks during setting to keep the concrete protected from the direct rays of the sun and covered with a few inches of water or wet material for the first fourteen days or so at least. In the case of a reservoir bottom it is frequently possible to keep two or three inches of actual water on this, which can safely be set upon it the day after it has been cast. In the case of roads, expansion joints should be provided at frequent intervals not farther apart than 50 ft., and the concreting should then proceed from one expansion joint to another in a single operation without any construction joints between. It should then be covered with wet material so as to retain the moisture for at least fourteen days, or longer if possible, the wet material being kept wet by applications from a hose from time to time as necessary.

VITRIOL TANKS.

Question.—Is it possible to construct reinforced concrete tanks to store vitriol? If so, what means should be adopted.—Swansea.

Answer.—Reinforced concrete itself will not resist the action of vitriol, but it is quite possible to construct reinforced concrete tanks for storing vitriol provided they are efficiently lined to prevent the vitriol coming in contact with the concrete. An acid-resisting asphalte can be used for this purpose, but great care has to be exercised in the use of this material as the strength of the vitriol seems to make a good deal of difference. Lead covering is also a method of protecting the concrete from the action of vitriol.

CONCRETE PRODUCTS

In view of the increasing demand for pre-cast concrete goods, and of the size to which the concrete products industry has now grown, we propose in future to give more space in each issue to developments in the manufacture and uses of these articles. Descriptions and illustrations of new concrete products or new applications of concrete, for publication in this section, will be welcomed.

REINFORCED CONCRETE SAFES.

REINFORCED concrete is a material which is constantly being put to fresh uses, and one of its interesting present-day applications is in the making of safes and strong-room doors.

When the high fire-resistance of good concrete, and the ease with which it can be moulded into any shape or form and reinforced, are considered, it will be recognised that concrete is a most suitable material for the purpose. An even more important advantage is the resistance offered by concrete to the oxy-acetylene blow-pipe—the deadly enemy of steel safes.

The " Fortis " reinforced concrete safes illustrated in this article are of monolithic construction, ensuring great strength

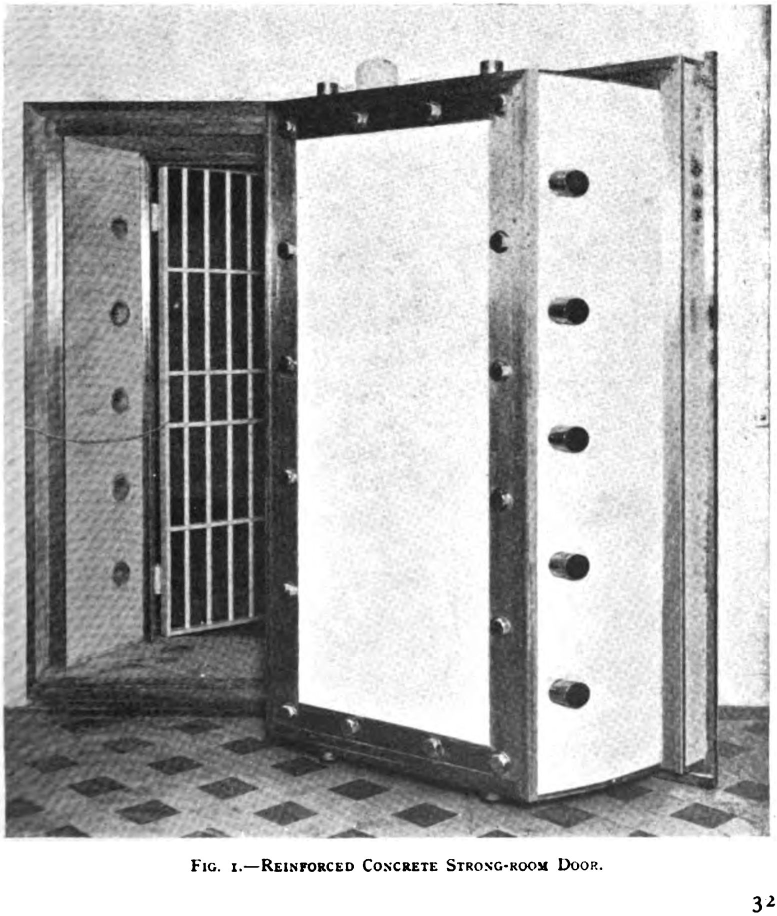


FIG. 1.—REINFORCED CONCRETE STRONG-ROOM DOOR.

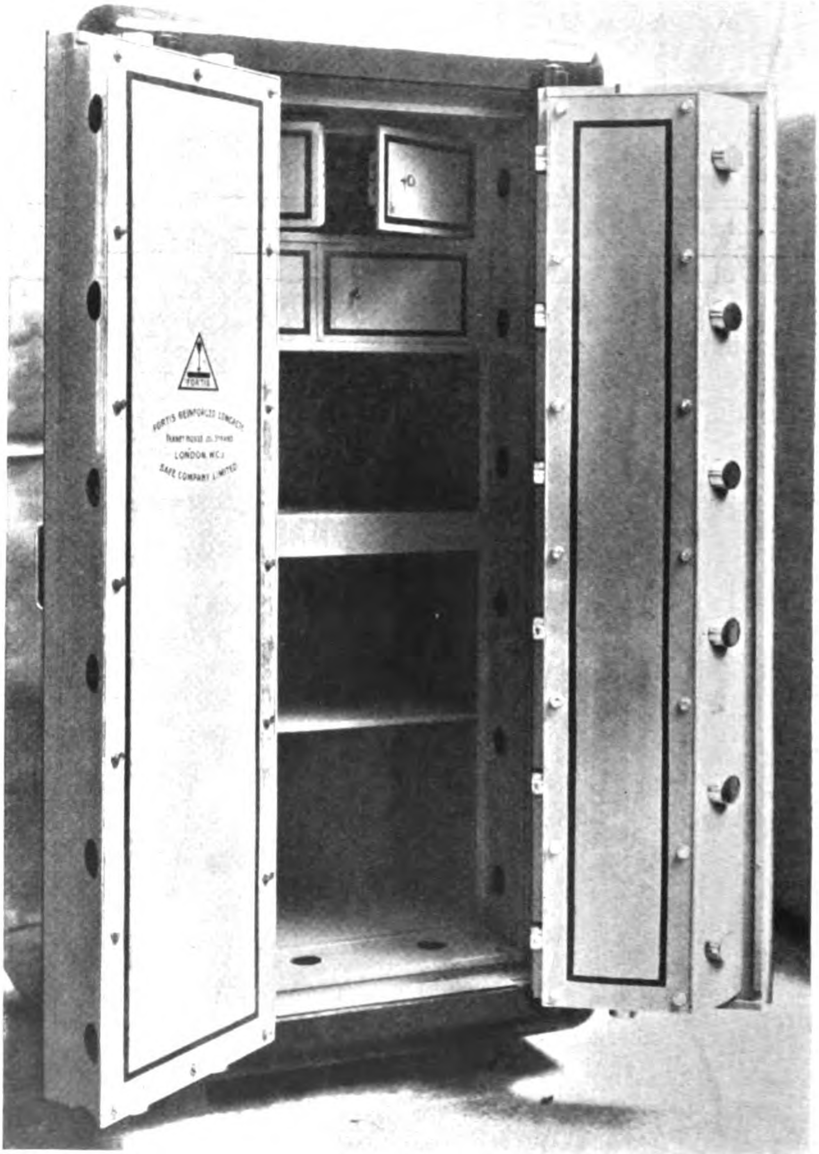


Fig. 2.—REINFORCED CONCRETE SAFE.

and rigidity and eliminating all joints, rivets, and the back as a separate piece. Not only the body but the door also is of reinforced concrete, the edge of the door having a steel strip around the closing edge which fits into a corresponding steel strip around the body. The close fit of the door into the safe is also unique, and can be seen from Fig. 4, which shows a typical cross-section through a safe.

The use of reinforced concrete in safe construction as the main material is so novel that many people find difficulty in realising the great merits of this material when used in safes which have been designed with a knowledge of its properties. It should be made clear that these safes are not steel safes filled with concrete, but almost entirely of reinforced concrete ; the only exposed steel are the pivots, fittings, and the light steel frames around the edges of door and body.

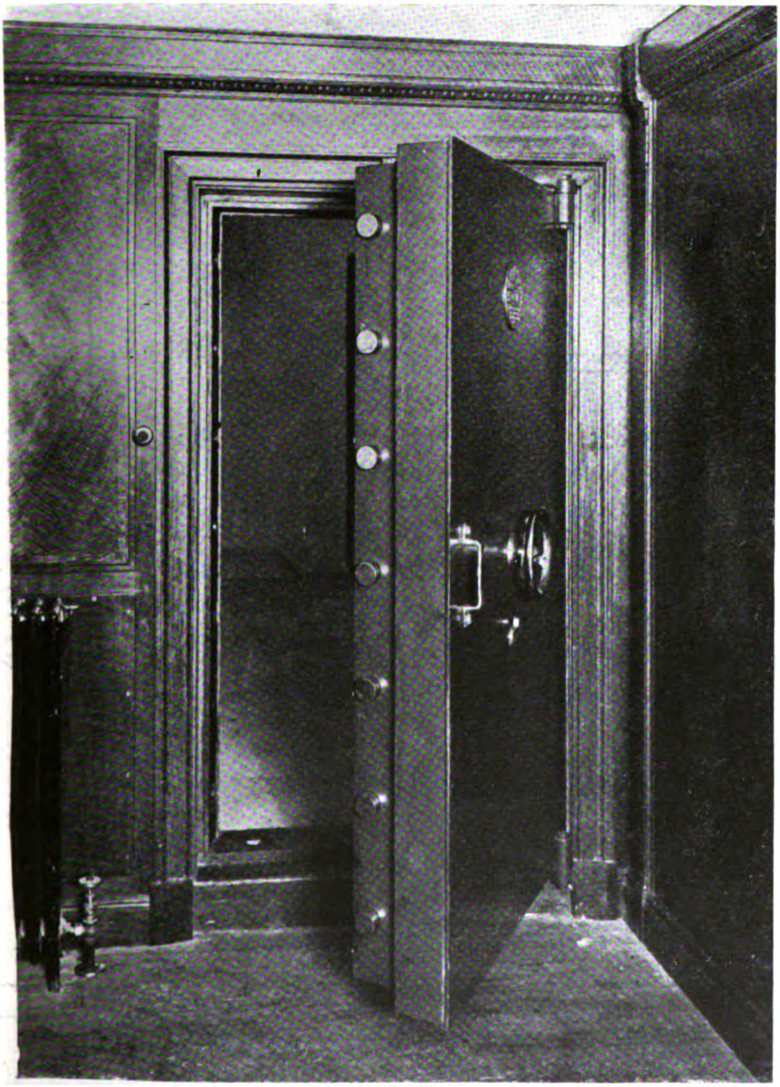


Fig. 3.—Reinforced Concrete Strong-room Door.

In considering the fire-resistance of these safes special provision has been made to prevent any possibility of flames or incandescent gases penetrating into the interior through the closing edge of the door. In addition to the close fitting of the door into the jamb, a fire-check is provided, consisting of a steel frame on the door, which fits into a corresponding frame in the body. Both these frames are insulated by concrete from the exterior of the safe.

It should be noticed that the fire-resistance depends on the material itself, and not on any moisture-generating composition, and furthermore, owing to the low conductivity of concrete, scorching of papers, etc., in an intense fire is prevented. The reinforcement of the safes is protected by a substantial thickness of concrete, and there is no steel or iron running from the exterior into the interior, by which heat might be transmitted.

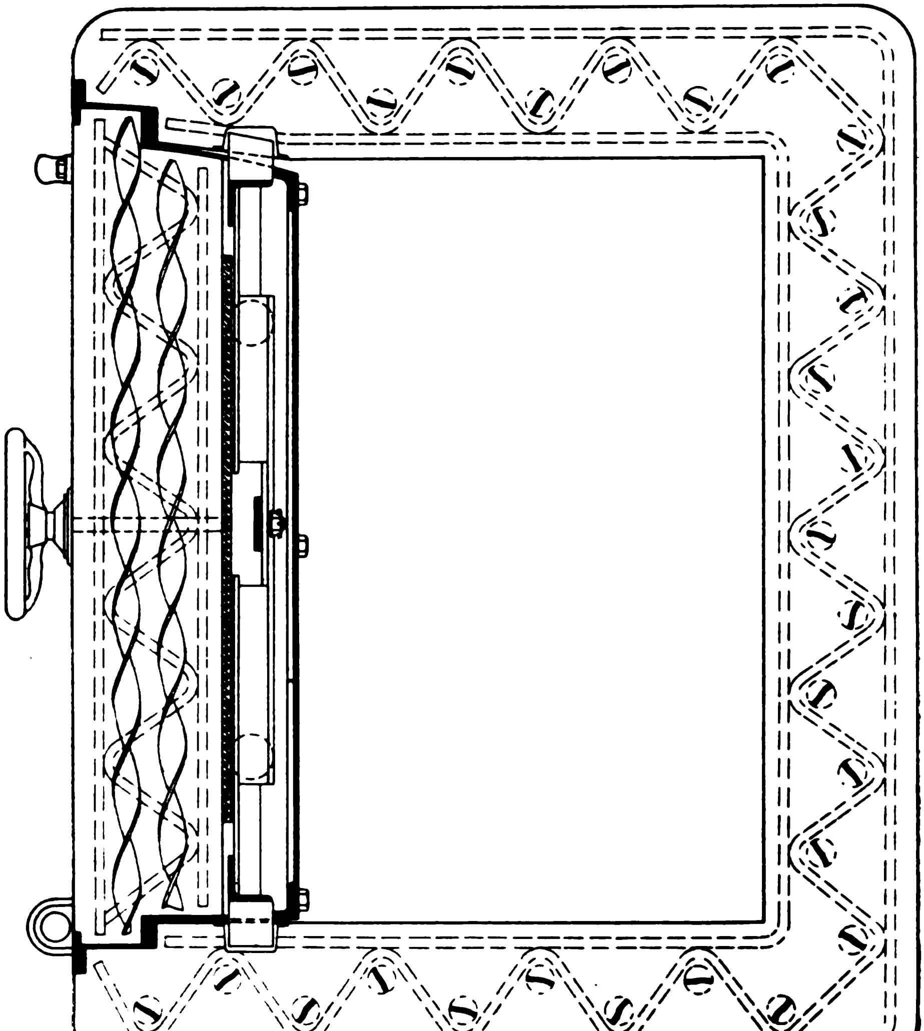


Fig. 4.—The "Fortis" Reinforced Concrete Safe: Cross Section.

It will be obvious that such safes, of monolithic construction and with continuous reinforcement, are very rigid, and tests have proved resistance offered to damage in the event of a fall from a height.

The reinforcement varies according to the size and purpose for which the safe is required, but a typical method is indicated in Fig. 4. In addition to the reinforcement used to give strength and rigidity to the safes, twisted bars of hard steel are employed, which provide an edge of steel protected by concrete, thus supplying increased resistance to cutting implements.

The locking and bolting system is in accordance with modern practice. Bolts of bright-drawn steel secure the doors on all sides, and shoot into sockets in the concrete frame or body. The bolting system is mounted on a steel plate covering the back of the door, which serves as an additional protection as well as providing a base for the bolting system. The additional security obtained by placing the lock at the back of the concrete and steel plate is apparent.

These safes are painted in any desired colour and fitted with nickel fittings. They are somewhat heavier than steel safes, which may be considered an advantage in view of the frequent cases of safes being removed bodily from premises by burglars.

Strong-room doors are also made of concrete, varying from $4\frac{1}{4}$ in. to 20 in. thick, according to the purpose for which they are required. Fig. 3 shows a 6 in. concrete door at a large store in London, and Fig. 1 shows a 20-in. door weighing four tons at a bank in Paris.

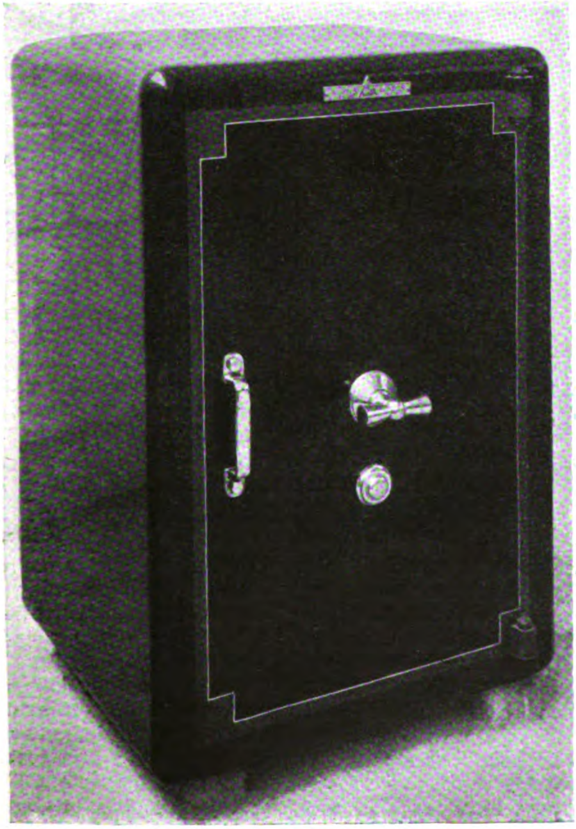


FIG. 5.—REINFORCED CONCRETE SAFE.

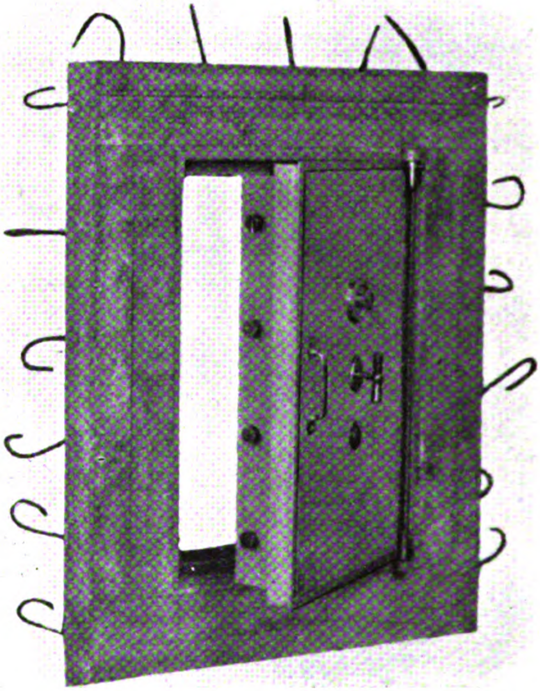


FIG. 6.—REINFORCED CONCRETE DOOR AND FRAME FOR WALL SAFE.

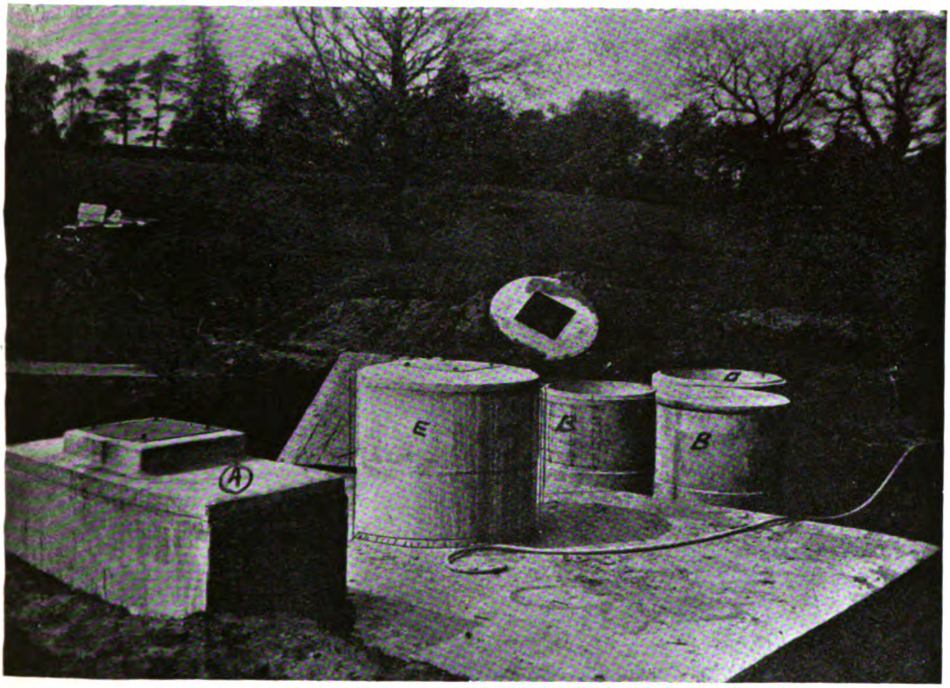
These doors, as also the safe doors, are carried on pivots, and in spite of the heavy weight they move very easily. The pivots are of special design, being anchored into the mass of concrete.

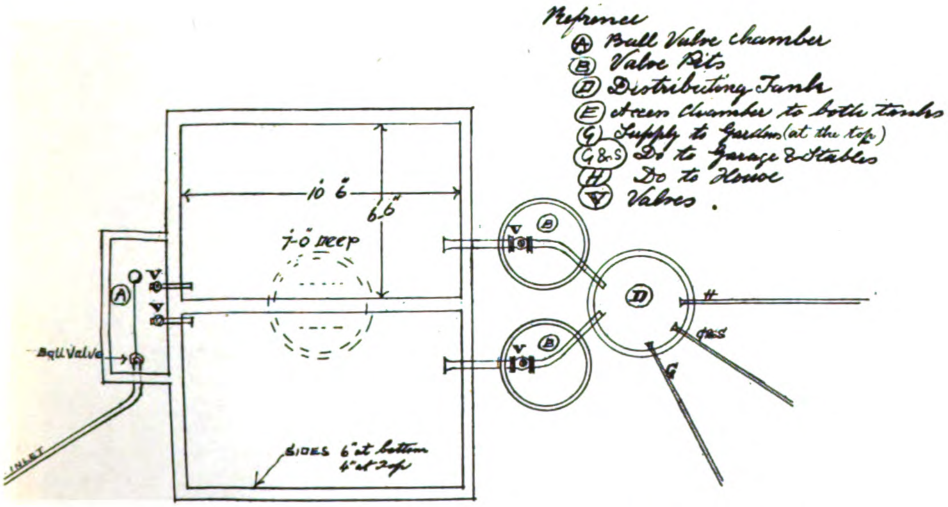
Fig. 6 is an illustration of a wall-safe, consisting of a reinforced concrete frame and door which can be built in position, in conjunction with brick or concrete walls, to form a small safe. These are primarily used for houses as plate safes, etc., but there should be many uses for small safe doors of this description.

These safes and strong-room doors are the invention of Mr. C. W. Thoerig, of Zurich, and the rights for Great Britain are owned by the Fortis Reinforced Concrete Safe Co., Ltd., of Thanet House, 231 Strand, London, W.C.2. The manufacture of these safes is carried out by their associated company, the Empire Stone Co., Ltd.

COUNTRY HOUSE WATER STORAGE.

THE duplicate set of water storage tanks illustrated on p. 329 were carried out by the Wharf Lane Concrete Co., Ltd., of Ilminster, to the plans of the Dillington Estate Office. The tanks are in reinforced concrete; the bottoms are 6 in. thick, the sides 6 in. at the bottom tapering to 4 in. at the top, and the covers 4 in., all reinforced with a mesh reinforcement. The circular tanks, which were pre-cast in sections, are adapted for the valve pits and distributing tank. Complete waterproofing of the tanks was obtained by carefully proportioning and mixing the concrete; the distributing tank is only 3 in. thick, but is completely watertight. The centre tank ("A") gives access to both the tanks below and ventilation is arranged through this ring so that nothing can be put into the tanks. A large ball valve with an iron cover over, operates in the square cistern ("A"). The two storage tanks are of 3,000 gallons capacity each.





CONCRETE WATER STORAGE TANKS AT A COUNTRY HOUSE. (*See p.* 328.)

NEW CONCRETE HOUSING SCHEMES.

After a lengthy discussion on a report by the Architect, the Edinburgh Town Council has now definitely decided to proceed with the erection of a further 1000 concrete cottages at Lochend.

The Carlisle Corporation has accepted the tender of Messrs. John Laing & Son, of Carlisle, for the erection of 50 concrete bungalows at a cost of £15,512 10*s*.

A tender for the erection of 30 concrete houses has been accepted by the Linthwaite Town Council.

A scheme for the erection of 200 concrete houses is under consideration by the Pudsey Town Council.

Among other housing schemes now under consideration are the following :—

Blaydon Urban District Council (300 houses).

Bolsover Urban District Council (50 houses).

Chelmsford Town Council (250 houses).

Dartford Urban District Council (28 houses).

Grimsby Town Council (52 houses).

Huddersfield Town Council (67 houses).

Longbenton Urban District Council (95 houses).

Market Rasen Urban District Council (a £15,000 scheme).

Orsett Rural District Council (200 houses).

Radcliffe Urban District Council (56 houses).

Redcar Town Council (50 houses).

Romford Urban District Council (40 houses).

Stoke-on-Trent Town Council (500 houses).

Workington Town Council (200 houses).

CONCRETE PAVING.

The following tenders have been accepted for the supply of concrete slabs for street paving :—

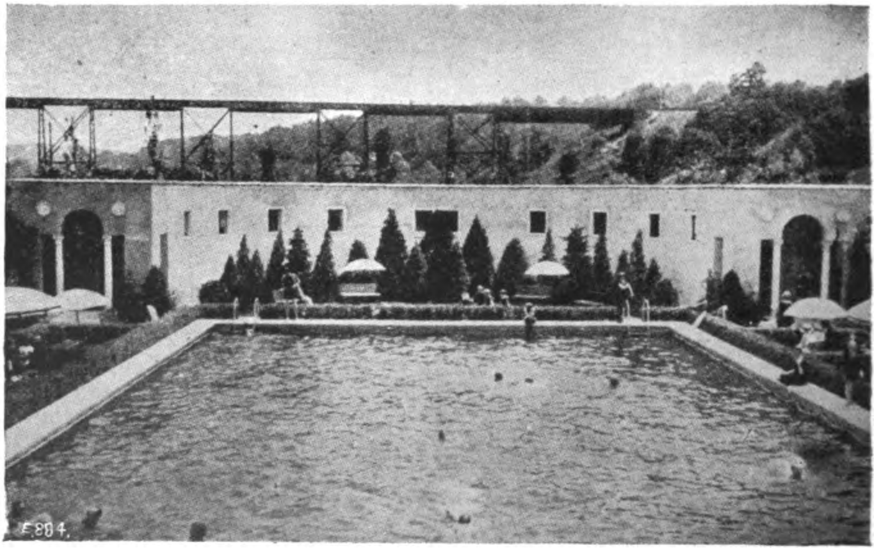
The Ilkeston Rural District Council has accepted a tender of Messrs. J. W. Stapleton & Son, of Ilkeston.

The Hammersmith Borough Council has accepted the tender of the Premier Artificial Stone Co., Ltd., for the supply of concrete slabs.

The Lewisham Borough Council has accepted the tender of the Alexandra Paving Stone Co., Ltd., for the supply of concrete paving at 5*s*. 10½*d*. per yd. super.

The Salford Highways Committee has accepted a tender of the Wigan Coal and Iron Co., Ltd., for concrete flags.

The tender of the Warrington Slate Co. has been accepted by the Wallasey Town Council for the supply of concrete flags at 5*s*. 5*d*. per sq. yd.



Concrete Swimming Pool, Built for use of Residents on a Housing Estate.

CRACKING OF CONCRETE ROADS.

AFTER a series of exhaustive tests on the cause and prevention of hair cracks in concrete roads, Mr. G. A. Macdonald, of the Ontario Department of Public Highways, has come to the following conclusions:—

(1) Cracking is the result of contraction caused by the loss of moisture from any cause when the concrete (cement or mortar) does not possess the required strength to overcome the outside restraining forces.

(2) An absorptive base hastens the time of setting of concrete and cement mortars—the greater the absorption the shorter the time of setting.

(3) An absorptive base tends to draw the cement and fine material away from the surface, leaving the larger aggregate above the general contour of the finish.

(4) An absorptive base does not permit the batches to bond together properly, owing to their stiffening in coming in contact with an absorptive medium.

(5) The tendency for slabs to crack increases with the increase in the ratio of length or width to depth. A 20-ft. pavement would crack to a greater extent than an 18-ft. pavement if the thickness remained the same.

(6) The richer the mix is in cement the greater the contraction, with an increased tendency to crack.

(7) Extra wet mixes may help to prevent cracking on moderately absorptive bases, but the resulting concrete is of low strength.

(8) With no loss of moisture the concrete tends to remain at constant volume.

(9) A saturated base prevents all losses by absorption, and may even supply moisture to the slab to replace losses by evaporation.

As a result of practical application in road work, the following procedure for the prevention of cracks is suggested:—

On completion of a day's work the sub-soil should be watered in preparation for the next day's work. Sufficient water should be put on it and at such intervals so that it will not lie in pools or make the sub-soil sticky. When the laying of the concrete is commenced the area in front of the mixer should be well watered: this should bring about a condition close to saturation that would materially lessen the losses caused by absorption. If the concrete materials are placed on the subsoil in front of the mixer it will be more difficult to follow the above procedure.

For the prevention of evaporation losses, dry covers such as tarpaulins laid directly on the concrete tend to aggravate the condition by absorbing additional moisture. Covers on frames may prevent the sun from increasing the temperature, but they will not stop evaporation. It is therefore suggested that burlap strips 3 ft. in width, of double weight material and overlapping each other, be used. These are not so costly as tarpaulins, and the actual cost of handling them is much less than moving heavy frames. These burlap strips should be kept soaked with water, and placed in that condition on the concrete when it has obtained a set, so that the strips will not mar the concrete. The strips should be kept in a moist condition, and not removed until just before covering the road with earth. If this method be adopted a more uniform curing condition will result, and at a time when the concrete is in the greatest need of it.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ½ in. mesh	,,	15	0
Best British Portland Cement	per ton 58*s.* to	63	0
"Ferrocrete" Portland Cement	10*s.* per ton extra		

Boarding for Shuttering—

		Sawn. s.	*Sawn.* d.	*Wrot.* s.	*Wrot.* d.
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £25 0*s.* per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £25 10*s.* ,, ,,

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
7/16 in. to ½ in. Rounds	,,	13	6
⅜ in. Rounds	,,	14	6
¼ in. Rounds	,,	15	6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed with Clean Water in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per yard cube	45	6
Do.	do.	in columns	,, ,,	50	6
Do.	do.	in beams	,, ,,	50	6
Do.	do.	in floor slabs 4 in. thick	per yard super	5	4
Do.	do.	in floor slabs 6 in. thick	,, ,,	7	11
Do.	do.	in floor slabs 9 in. thick	,, ,,	11	6
Do.	do.	in walls 6 in. thick	,, ,,	8	2

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	24	0
,, 7/16 in. to ½ in.	,,	23	0
,, ⅝ in. to 2⅞ in.	,,	22	0

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.*

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.*

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	55	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	51	0
Do. do. in small quantities	per ft. super	0	9½
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last, in narrow widths	,, ,,	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	,, ,,	1	1
Do. do. as last, in narrow widths	,, ,,	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are those current in the London area, namely:—Carpenters and joiners, 1/8 per hour; Labourers on building works, 1/3; Operators on concrete mixers and hoists, 1/4.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

PROSPECTIVE NEW CONCRETE WORK.

Ashburton.—*Paving.*—The U.D.C. proposes to renew in concrete certain portions of the pavements in East and West Streets.

Blaydon.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to the lay-out of the Bleach Green estate, which will provide for 300 houses.

Boldon.—*Road.*—The South Shields R.D.C. proposes to construct a road from Leam Lane to Boldon Colliery, estimated to cost £106,500.

Bolsover.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to erect 50 houses in the Shuttlewood district.

Chelmsford.—*Houses.*—The Corporation has applied to the M.H. for sanction to the erection of 250 houses.

Clacton-on-Sea.—*Bathing Pool.*—The U.D.C. proposes to construct a bathing pool on the West Beach, estimated to cost £25,000.

Cuckfield. — *Bridges.* — The R.D.C. proposes to reconstruct in concrete several bridges in the district.

Dartford.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to borrow £13,030 in connection with the erection of 28 houses on the Lowfield Street estate.

Edinburgh.—*Houses.*—The Corporation has decided to proceed with the scheme for the erection of 1000 concrete houses at Lochend.

Fleetwood.—*Open-Air Baths, etc.*—The R.D.C. has applied for sanction to borrow £25,045 for the construction of open-air baths and development of the foreshore.

Grimsby.—*Houses.*—The T.C. has applied to the M.H. for sanction to borrow £26,100 for the construction of 52 houses at Nunsthorpe.

Hamer.—*Bridge.*—The Rochdale Corporation proposes to construct a bridge at Hamer.

Huddersfield.—*Houses.*—The T.C. has applied to the M.H. for sanction to erect 67 houses at Paddock.

Hylton.—*Bridge.*—The Sunderland R.D.C. has under consideration a scheme for the construction of a bridge over the Weir, estimated to cost £50,000.

Leith.—*Houses.*—The Edinburgh Corporation has approved a scheme for improving and clearing the slums at Leith Port, estimated to cost £386,000.

Longbenton.—*Houses.*—The U.D.C. proposes to construct 95 houses on the Glebe estate, estimated to cost £44,000.

Longton. — *Paving.* — The Stoke-on-Trent Corporation Highways and Plans Committee has decided to pave with concrete a portion of Wharf Street, estimated to cost £3,250.

Market Rasen.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to borrow £15,000 in connection with the construction of houses.

Orsett.—*Houses.*—The R.D.C. has applied to the M.H. for sanction to erect 200 houses.

Pudsey.—*Concrete Houses.*—The T.C. proposes to construct 200 concrete houses.

Radcliffe. — *Houses.* — The Council proposes to erect 56 houses at Black Lane at a cost of £482 each.

Redcar.—*Houses.*—The T.C. proposes to construct 50 houses, estimated to cost £400 each.

Romford.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to erect 40 houses on the housing estate at London Road.

Stoke-on-Trent. — *Houses.* — The Housing Committee recommends the erection of 500 houses.

Thurnsvoe.—*Reservoir.*—The U.D.C. proposes to construct a reinforced concrete reservoir with a capacity of 600,000 gallons.

Troedyrhiw.—*Bridge.*—The Merthyr Corporation has approved of the reconstruction in reinforced concrete of Pontyythim Bridge.

Workington.—*Footpaths.*—The T.C. proposes to construct concrete footpaths in connection with the scheme for widening Moss Bay Road.

Workington.—*Houses.*—The T.C. has applied to the M.H. for sanction to erect 200 houses.

TENDERS ACCEPTED.

BOSTON.—*Bridge.*—The R.D.C. has accepted the tender of the Yorkshire Hennebique Co., at £5,200, for the erection of a ferro-concrete bridge at Mainridge.

CARLISLE. — *Bungalows.* — The City Council has accepted the tender of Messrs. John Laing & Son, Carlisle, at £15,512 10*s.*, for the erection of 50 concrete bungalows.

HAGLEY.—*Reservoir.*—The Stourbridge and District Water Board has accepted the tender of Mr. A. E. Farr, Great St. Helens, London, E.C.3, at £3,090, for the construction of a reinforced concrete reservoir of about 352,000 gallons capacity.

HONITON.—*Bridge.*—The R.D.C. has recommended for acceptance the tender of Messrs. Fothergill Bros., Exeter, at £1,131 8*s.* 4*d.*, for the construction of a concrete bridge at Howley Ford.

ILKESTON.—*Slabs.*—The R.D.C. has accepted the tender of Messrs. J. W. Stapleton & Son, Ilkeston, for the supply of concrete slabs.

KIRKCUDBRIGHT.—*Bridge.*—The Kirkcudbrightshire C.C. has accepted the tender of Messrs. J. Angus & Sons, Edinburgh, at £29,150, for the construction of a ferro-concrete bridge over the River Dee.

LINTHWAITE.—*Concrete Houses.*—The T.C. has accepted a tender for the construction of 30 concrete houses.

LIVERPOOL.—*Works.*—The City Council has accepted the tenders of Messrs. J. Henshaw & Son, for the construction of a concrete engine-bed at £218, and structural alterations and completion of a concrete engine-bed at £640.

LONDON (HENDON).—*Sewage Disposal Works.*—The U.D.C. has accepted the tender of Messrs. W. Moss & Sons, at £59,658 10*s.* 5*d.*, for the construction of sewage disposal works.

LONDON (LEWISHAM).—*Paving.*—The B.C. has accepted the tender of the Alexandra Paving Stone Co., Ltd., for the supply of artificial stone paving at 5*s.* 10½*d.* per yard super.

OAKHAM.—*Bridge.*—The Rutland C.C. has accepted the tender of Messrs. W. Higgs & Sons, Oakham, at £335, for work in connection with the widening of Preston Hollow Bridge in reinforced concrete.

TADCASTER. — *Sewage Works.* — The R.D.C. has accepted the tender of Messrs. J. A. Rodgers & Sons, at £1,119 6*s.* 8*d.*, for the construction of sewage works at Barwick.

TEIGNMOUTH.—*Retaining Wall.*—The Gas Committee has accepted the tender of Messrs. Saxild & Partners, 2, Central Buildings, S.W.1, for the construction of a 190-ft. retaining wall.

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H.M. KING GEORGE V

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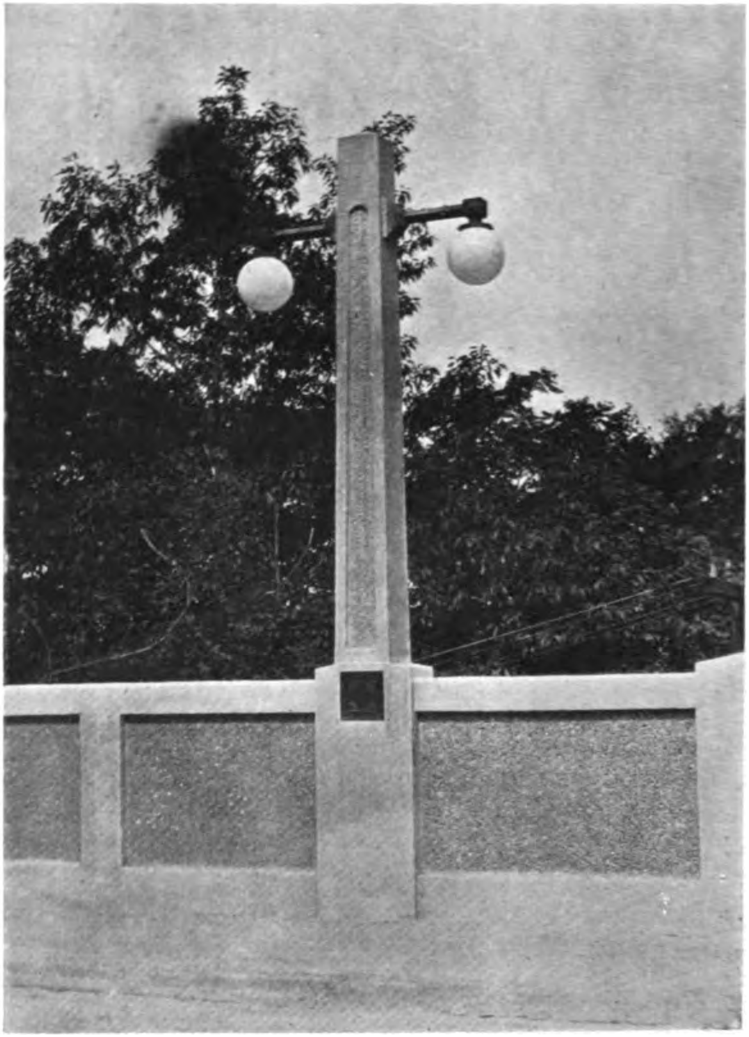


LAMP-POST AND PARAPET (cast *in situ*):
SHOWING EXPOSED AGGREGATE SURFACE TREATMENT.

Reinforced Concrete Bridge built around an old Steel Structure at Pulaski, N.Y.
(*See p.* 361.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIX. No. 6 LONDON, JUNE, 1924

EDITORIAL NOTES.

THE STRENGTH OF REINFORCED CONCRETE STRUCTURES.

IN the design of reinforced concrete structures calculations are based upon certain theories which have gradually been built up as our knowledge of the action of the composite material has progressed. In many cases the distribution of stresses in practice is of a highly complicated nature, so that the results of our formulæ may only represent an approximation to the stresses actually occurring in the steel and concrete. It thus follows that in addition to theoretical investigations we require to study the result of researches involving the loading of actual structures or structural elements which have been made by scientific investigators ; we can then revise our methods of calculation in the light of the experimental results.

A large amount of test information on reinforced concrete structures is now available, but the original papers are not always accessible nor are the results always in such form that busy practical designers find it an easy matter to follow the application of the results of the tests to practical design. In the series of articles by Mr. Ewart S. Andrews commencing in the present issue it is proposed to deal in detail with the results of some of the leading loading tests on reinforced concrete structures, and to study them in special reference to the results obtained by the results of calculations made upon the orthodox theories usually obtaining in this country. We hope by this means to provide designers with information which will guide them in their work in cases in which there is some difference of opinion as to the most satisfactory theory upon which to base their calculations.

SURFACE-TREATED CONCRETE.

So far as we are aware the new " Fortune " Theatre, situated behind The Theatre Royal, Drury Lane, is the first building to be erected in London where no covering material has been applied to the exterior concrete walls. The film of cement was removed from the surface, by bush-hammering and other means, to expose the coloured aggregate. A pink coloured stone was used for the aggregate, which harmonises well with the horizontal dark metal bands with which the building is decorated. A further point of interest in this building is the thinness of the outside walls ; these are only 5 in. thick, and are a convincing reply to the statement so often heard that reinforced concrete buildings are unsuited to London sites on account of the " valuable ground which would be wasted by the additional thickness required for reinforced concrete walls." In this case reinforced concrete was chiefly selected for the purpose because of the small amount of ground space it would occupy compared with a steel frame faced with stone.

CONCRETE SCULPTURE.

With the increasing use of concrete as a structural material comes of necessity its consideration as a decorative material, and it is logical to suppose that sooner or later sculpture in concrete or cement will be regarded as one of the means of decorating concrete buildings. Except in so far as the actual material is concerned, there is nothing particularly new in the use of sculpture moulded in this way. All are familiar with the relief figures of the Adam period, which were executed in plaster. Many of these figures make delightful incidents for interior decoration, and it is perhaps a matter of surprise that greater efforts have not been made to use similar figures externally. It is, of course, evident that plaster of Paris is unsuitable as an external material, because it must rely for its permanence solely upon the protection afforded by paint or varnish. Cement, on the other hand, is a permanent material without the addition of paint, and may be used either in its natural colour or decorated by means of paint. There can be no æsthetic objection to the use of either cement or concrete for the purposes of sculpture decoration. If the view is taken that only costly materials should be used to preserve the art of the modeller then severe limitations are imposed, because in many cases price excludes any such use. In the nineteenth century, and particularly in the period of the Classic revival, architects accepted sculpture for its own sake, and executed it as permanently as possible: this seems a reasonable and legitimate view. On the score of permanence Portland cement is at least equal to marble, and therefore can be criticised only on the ground that it is not a precious substance. Many pleasant surface treatments may be used; Mrs. Phœbe Stabler has for some years exhibited concrete figures in which the roughness of the texture of the material has been one of the attractions of the work. This use of the material achieves a certain unity with the concrete structure, which is a very valuable quality.

There are certain inherent objections to many forms of concrete sculpture on a large scale if they are executed in the round, because they are liable to damage unless extensively reinforced. The risk of expansion of the steel, and the consequent destruction of the figure, is not a risk which the artist should be called upon to run. In dealing with concrete sculpture in the round there is ample scope for the exercise of new faculties. The figure or groups must be specially designed for the material and will differ in technique from work either in stone, marble, or bronze. This concrete technique is open for development, and may form the basis of much that is both new and interesting. Something of the structural character of concrete may similarly be evolved by special attention to the handling of reliefs, and incised work with little or no surface modelling may become a recognised means of dealing with the material.

The application of colour opens up a vista of treatments in which various coloured aggregates are added in layers and the material cut away so that these colours are exposed. There is some affinity between the mass of concrete building and the mass of the work of the ancient Egyptians. There may similarly be some affinity between the most appropriate methods of handling the sculpture. Both cement and concrete lend themselves to decorative treatment on the part of the sculptor, and architects will no doubt make these materials a serious factor in future schemes of decoration.

WIND PRESSURES.

In a third report on the measurement of the pressure of wind on structures, to be brought forward for discussion at the Institution of Civil Engineers, Mr. T. E. Stanton, C.B.E., D.Sc., deals with the effect of the lateral variations in velocity of actual winds and describes the determination of the mean pressure of the wind on the high-level footway girders of the Tower Bridge and the relation of this mean pressure to the pressure at a reference point in the surface of the girder. It is shown that for bridges of spans up to 250 ft. the effect of the lateral variation in velocity of the wind is not sufficient to admit of any considerable reduction in the wind-pressure factor on this account, and the conclusion is reached that until further experiments have been made on still larger structures, of spans exceeding 2,000 ft., wind-pressures should be calculated from the records of anemometers on the site and on the assumption of a velocity of wind uniform over the whole structure.

This Report is the third section of the investigation on wind-pressure commenced at the National Physical Laboratory in 1903. The first Report described experiments in a wind-channel on small-scale models of structures and gave information on the relative effect of the form and distribution of the solid surfaces of structures. The second Report was devoted to tests in the open air on plates and model roofs and girders up to 100 sq. ft. in area, and showed that the effect of the difference in size between these structures and the small-scale models used in the wind-channel tests was practically negligible, provided the velocity of the wind was uniform in a direction perpendicular to its direction.

CONCRETE ROADS IN AMERICA.

The volume of concrete roads built in the United States during the year 1923 amounted to approximately 74,000,000 sq. yds. Of this amount 62,000,000 sq. yds.—the equivalent of almost 5,900 miles of concrete road 18 ft. wide—were added to the nation's permanent highway system. The balance—12,000,000 sq. yds.—was placed on city streets and alleys. In 1921, the previous record year with its ideal construction conditions, approximately 63,000,000 sq. yds. or 84 per cent. of the 1923 yardage, were constructed, including street and alley work of this type. The concrete pavement completed in 1922, despite the unfavourable conditions that year, was very nearly equal in amount to that placed in 1921. Of especial significance is the rapid increase in the yardage of concrete pavements placed within city limits. The 12,000,000 sq. yds. of concrete pavement placed in American cities during 1923 is double the amount laid in 1921, and surpasses the 1922 yardage by 5,000,000 sq. yds. It is an indication of the rapidly growing esteem in which this type of pavement is held for street improvement.

The construction of 74,000,000 sq. yds. of concrete pavement in a single short season is significant. That a comparatively new construction industry, developed within only a few years, was able to accomplish work of such proportions, represents an achievement of which American road builders may well be proud.

NOTES ON MOMENTS IN PILLARS DUE TO DEFLECTION OF BEAMS MONOLITHIC THEREWITH.

By **OSCAR FABER, O.B.E., D.Sc., M.Inst.C.E.**

THE bending of pillars due to the deflection of beams monolithic with them has been touched upon in "R.C.S.E."* Chapter V, but it is felt that a further explanation is desirable.

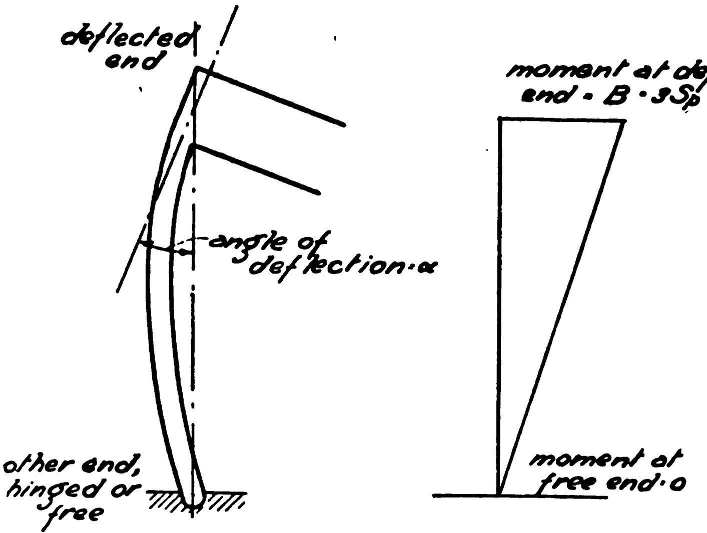
If a pillar, originally vertical and straight, with one end (i.e. the lower end) held in position but not in direction by a form of fixing approximating to a hinge, has the other end (i.e. the upper end) deflected through a certain angle a (see *Fig.* 1), then it can be shown that the bending moment in the pillar at the deflected end can be expressed by the formula

$$B = 3\frac{I}{l}Ea \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where I = Moment of inertia of pillar,
l = Length of pillar,
E = Young's modulus of the material of the pillar,
a = Angle of deflection.

---

* R.C.S.E. indicates "Reinforced Concrete Simply Explained," by the author.


deflected end
angle of deflection·α
other end, hinged or free
moment at deflected end · B · 3Sp Eα
moment at free end·0

(a) CONDITIONS OF ENDS AND LINE OF CURVATURE

(b) DISTRIBUTION OF MOMENT IN PILLAR

FIG. 1

PILLAR WITH ONE END DEFLECTED AND OTHER END FREE

The distribution of bending moment is given by *Fig.* 1*b*, showing that it varies from a maximum at the bent end to zero at the free end.

If for $\frac{I}{l}$ we substitute S_p, the stiffness factor of the pillar, the expression may be written

$$B = 3S_pEa \qquad \qquad (1a)$$

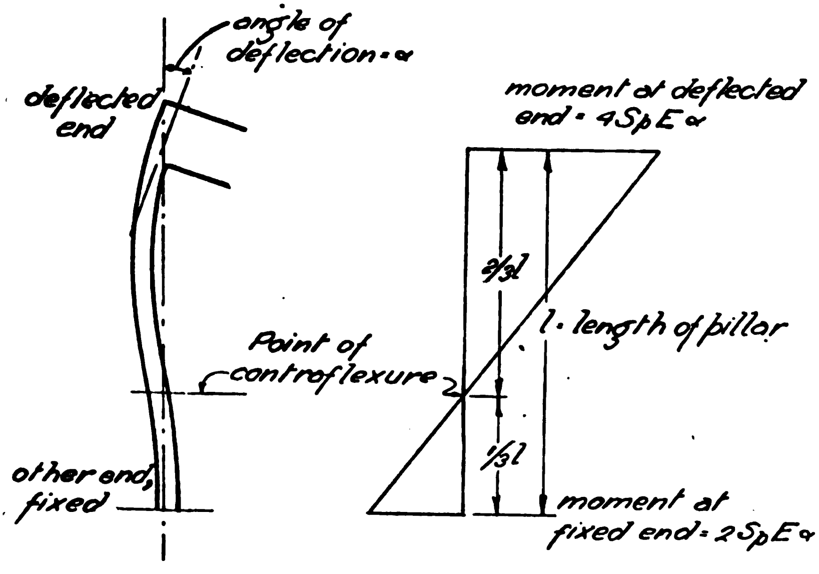
Note, in passing, that, except for the factor 3, it is obvious with a little consideration that the moment must vary with the quantities in the formula. One's personal experience with common objects should make the following remarks obvious. Let us consider them in order.

CASE I.—The moment of inertia (which, for a plain rectangular section is given by

$$I = \frac{bd^3}{12},$$

where b is the breadth and d the depth of the section) is a measure of the stiffness of the section, and obviously the stiffer the section the greater will be the moment necessary to deflect the end through a given angle.

The length, on the other hand, makes for flexibility, which explains why the moment varies *inversely* with the length. Clearly a long pillar of a given section is more easily deflected through a given angle than a short one.



(a) CONDITIONS OF ENDS AND LINE OF CURVATURE

(b) DISTRIBUTION OF MOMENT IN PILLAR

FIG. 2

PILLAR WITH ONE END DEFLECTED AND OTHER END FIXED IN DIRECTION.

Young's Modulus (see " R.C.S.E.", par. 7) is a measure of the stress required to produce a given strain or change of shape, and clearly it requires a larger moment to deflect a pillar of a high modulus (such as steel) than one of the same section but of a low modulus (such as india-rubber) through the same angle.

The remaining expression is the angle through which one end of the pillar is deflected, and here again it is clearly common experience that it requires a larger moment to deflect the pillar through a large angle than a small one.

The author would remark in passing that it is very important, in his view, to realise the meaning of a formula in this way, so that instead of representing so many dead algebraic symbols it may become live with the truth of common experience, when it loses its terrors and becomes a simple statement of a simple fact which can be tested by anyone with sufficient energy and interest to desire it.

CASE II.—If, now, we consider a pillar having its bottom end fixed in posi-

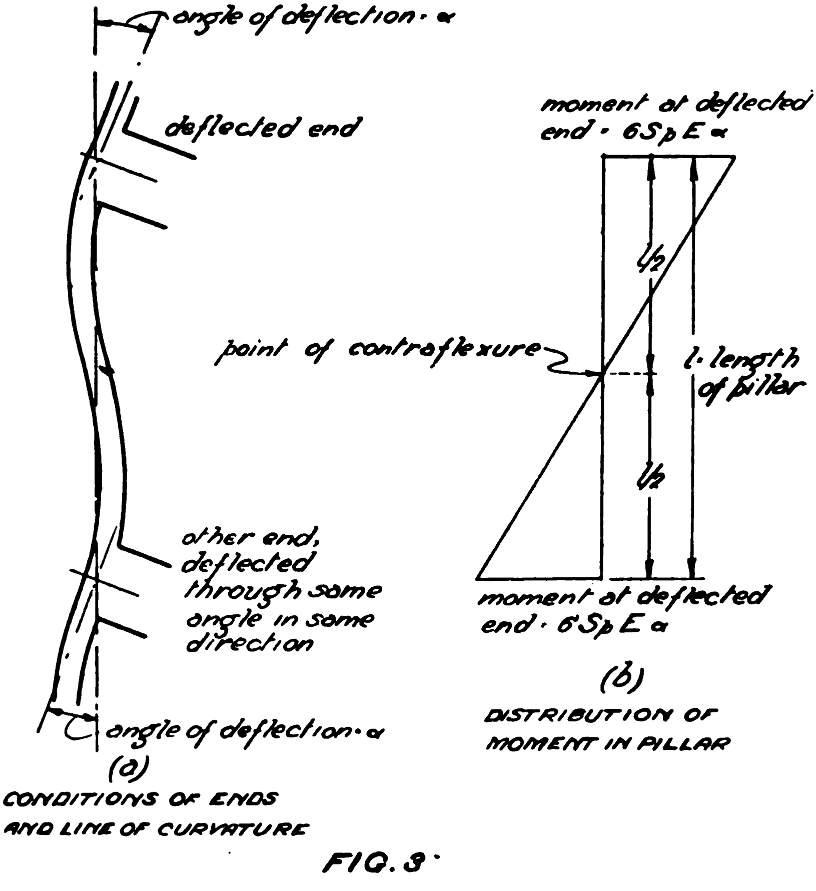

angle of deflection · α
deflected end
moment at deflected end · 6SpEα
l/2
point of contraflexure
l · length of pillar
l/2
other end, deflected through same angle in same direction
moment at deflected end · 6SpEα
angle of deflection · α
(a)
CONDITIONS OF ENDS AND LINE OF CURVATURE
(b)
DISTRIBUTION OF MOMENT IN PILLAR

FIG. 3.

PILLAR WITH BOTH ENDS DEFLECTED THROUGH SAME ANGLE IN SAME DIRECTION

tion and direction, and its upper end deflected through a certain angle a, then it can be shown that the moment which has to be exerted at the top may be expressed by

$$B = 4S_pEa \qquad . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (2)$$

and the distribution of moment is given in *Fig.* 2 (*b*) which shows that there is a moment of $2S_pEa$ at the restrained end, and a point one-third the length therefrom where the moment is zero and the curvature changes (called a point of contraflexure).

CASE III.—If a pillar, originally straight and vertical, has both ends deflected through an angle a ***in the same direction*** (see *Fig.* 3), it can be shown that the moment at the ends is given by

$$B = 6S_pEa \qquad . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (3)$$

and the distribution of moment is as in *Fig.* 3.

CASE IV.—If a pillar, originally straight and vertical, has both ends deflected through an angle a ***in opposite directions*** (see *Fig.* 4), it can be shown that the moment at the ends (and in this case throughout the length) is given by

$$B = 2S_pEa \qquad . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (4)$$

Now each of these cases approximates in some degree to pillars under practical conditions, the deflection of the end being produced by that of a beam under load made monolithic with the pillar.

Case I approximates to the case of a pillar having its upper end monolithic with a flexible beam and its lower end free to rotate (as, for example, if it rests on a small footing on yielding subsoil).

Case II approximates to that of a pillar with its upper end monolithic with a flexible beam and its lower end fixed (as, for example, if it rests on a large footing on a subsoil free from yield, or is attached here to a very stiff beam and pillar).

Case III approximates to a pillar having both ends monolithic with floor beams on two floors which are so loaded as to deflect the ends equally in the same directions.

Case IV approximates to a pillar having both ends monolithic with floor beams in two floors which are so loaded as to deflect the ends equally but in opposite directions.

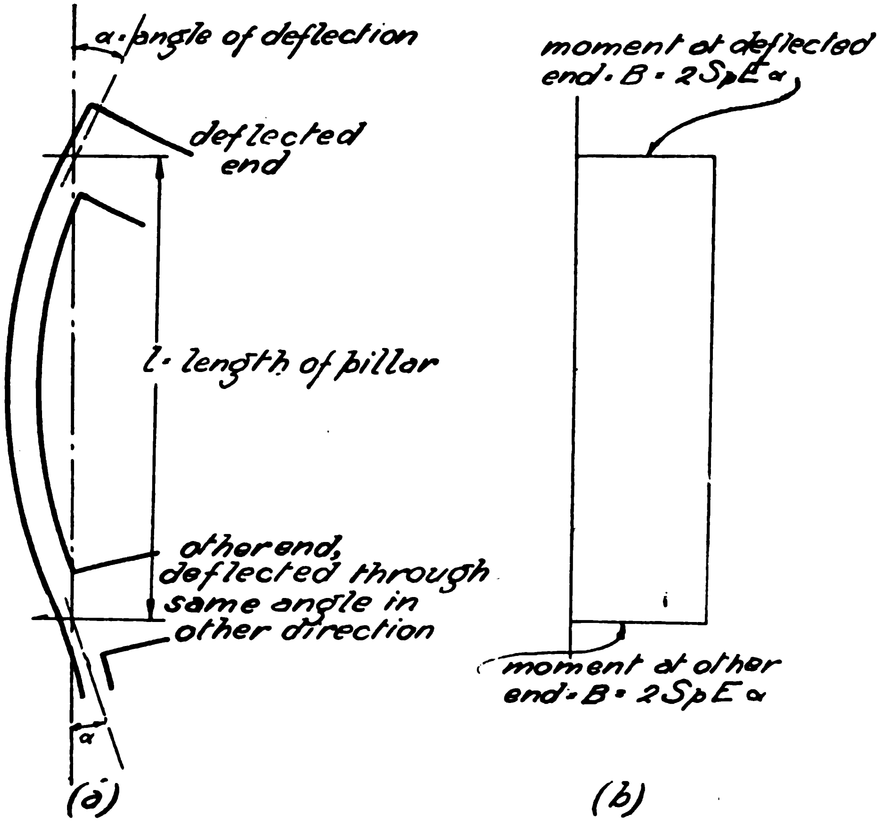
It will be seen that in all cases the moment in the pillar may be written in the form

$$B = F_pS_pEa \qquad . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (5)$$

where F_p is a factor, called the *fixity* factor (because it depends on the condition of fixity of the pillar) and which has the value of

3 in Case I,
4 in Case II,
6 in Case III,
2 in Case IV.

In practice it is unusual to find a case exactly represented by one of the above. Most cases lie intermediate. Cases do occur, however, in which F_p may have a higher value even than 6.


α = angle of deflection
deflected end
l = length of pillar
other end, deflected through same angle in other direction
α
(a)
moment at deflected end = B = 2SpEα
moment at other end = B = 2SpEα
(b)

(a) CONDITIONS OF ENDS AND LINE OF CURVATURE

(b) DISTRIBUTION OF MOMENT IN PILLAR

FIG. 4

PILLAR WITH ONE END DEFLECTED, AND OTHER. END DEFLECTED THROUGH SAME ANGLE IN OTHER DIRECTION.

The exact determination in any given case lies rather outside the scope of a simple exposition, and it must suffice here that Case II ($F_p = 4$) may be taken as a normal one for internal pillars, and Case III ($F_p = 6$) as a normal one for outside pillars.

The value of the moment in the pillar is given by the tables in " R.C.S.E.", pp. 54 and 55. It might be thought at first sight that it could be obtained direct from one of the formulæ 1 to 4 above, but these involve the expression α, the angle of deflection of one end of the pillar. This angle depends not only on the stiffness of the pillar but also on that of the beam. Clearly, if the beam were infinitely stiff, the angle of deflection would be zero.

It is therefore natural to expect this angle, and therefore the moment in the pillar (which depends on the angle), to depend on an expression involving the stiffness of the beam as well as that of the pillar, and reference to Tables II and III (" R.C.S.E.", pp. 54 and 55) shows that it depends on the expression

$$\frac{F_pS_p}{S_b}$$

where F_p is the fixity factor (2 to 6 as just explained)

S_p is the stiffness factor of the pillar, $\frac{I}{l}$

S_b is the stiffness factor of the beam, $\frac{I}{l}$

It will be noticed that in both tables the moment varies from $\frac{Wl}{12}$ when $\frac{F_pS_p}{S_b}$ is infinite, to zero when $\frac{F_pS_p}{S_b}$ is zero (which are the two extremes between which all practical cases lie). This again is reasonable and obvious with a little consideration.

Let us consider the case when $\frac{F_rS_p}{S_b}$ is infinite. This means the pillar is very stiff indeed in comparison with the beam. Under these circumstances any attempt to deflect the beam by loading it will be resisted by a very stiff pillar, so that for all practical purposes the end of the beam is fixed in direction, and it is well known that a beam uniformly loaded and having its ends fixed in direction will have a moment equal to

$$B = \frac{Wl}{12}$$

at the ends.

Consider now the case when $\frac{F_pS_p}{S_b}$ approximates to zero. This means that the beam is very stiff indeed in comparison with the pillar. Hence the deflection will be negligible, and as the pillar is very flexible a negligible deflection will exert only a negligible moment in it, when B will approximate to zero.

In practice, the end of a pillar generally enlarges into a beam section of

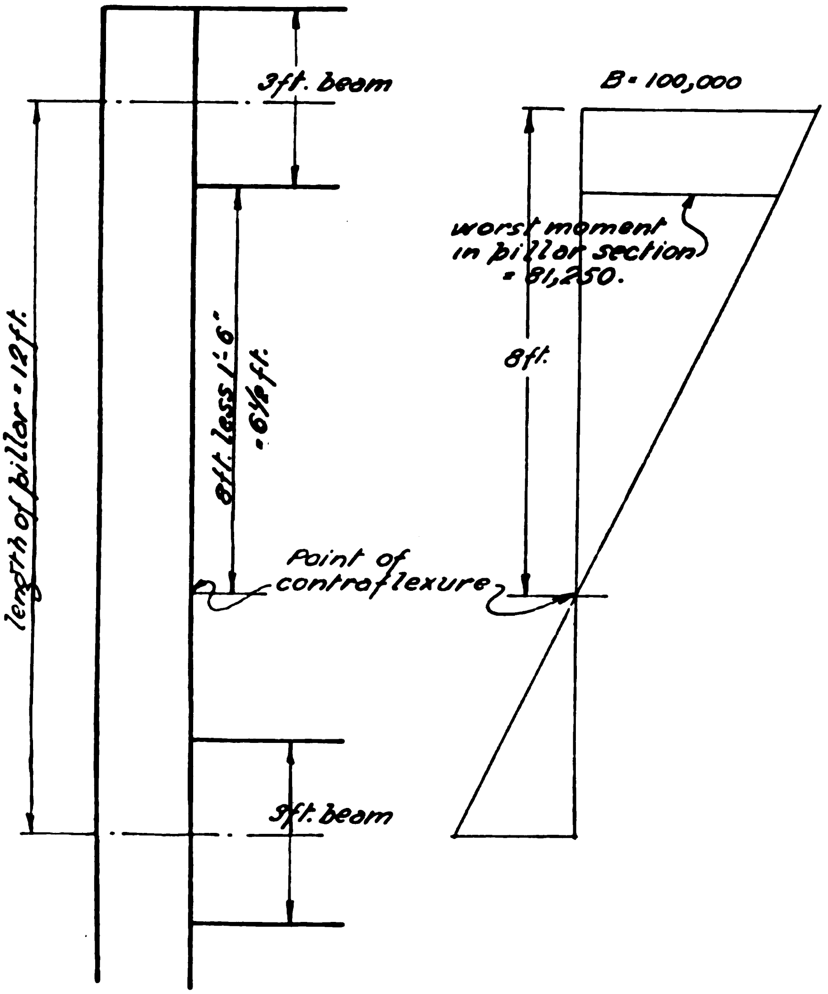


FIG. 5

SHOWING REDUCTION OF PILLAR MOMENT OWING TO DEPTH OF BEAMS OR HAUNCHES appreciable depth. The end of the pillar may then generally be taken at a point half-way up the height of the beam.

The worst straining action on the pillar then occurs at the bottom of the beam, or, if there is a haunch, at the bottom of the haunch.

Knowing the moment at the end, and the position of the point of contraflexure, it is then a simple matter to calculate the reduced moment at this section.

For example, suppose a certain interior pillar with its lower end fixed (see *Case II* and *Fig.* 2) has a moment at its deflected end of 100,000 in.-lbs. (calculated from Table III, " R.C.S.E.," p. 55). Suppose now the beam producing this deflection is 3 ft. deep and the pillar is 12 ft. high (see *Fig.* 5). Then the position of the point of contraflexure is

$$\frac{2}{3}l = 8 \text{ ft.}$$

from the end. But the bottom of the beam is half of 3 ft.—namely, $1\frac{1}{2}$ ft. below the end of the pillar. Hence the worst moment in the pillar section is reduced to

$$100{,}000 \times \frac{(8 - 1\frac{1}{2})}{8} = 81{,}250 \text{ in.-lbs.}$$

This reduction is often important.

If we were considering an outside pillar and the case approximated to *Case III* (*Fig.* 3), we should take the point of contraflexure half-way down, and the reduction of moment would be still more marked.

It will be seen that deep haunches may considerably reduce the stresses in this way.

THE USE OF PROFESSIONAL AFFIXES.

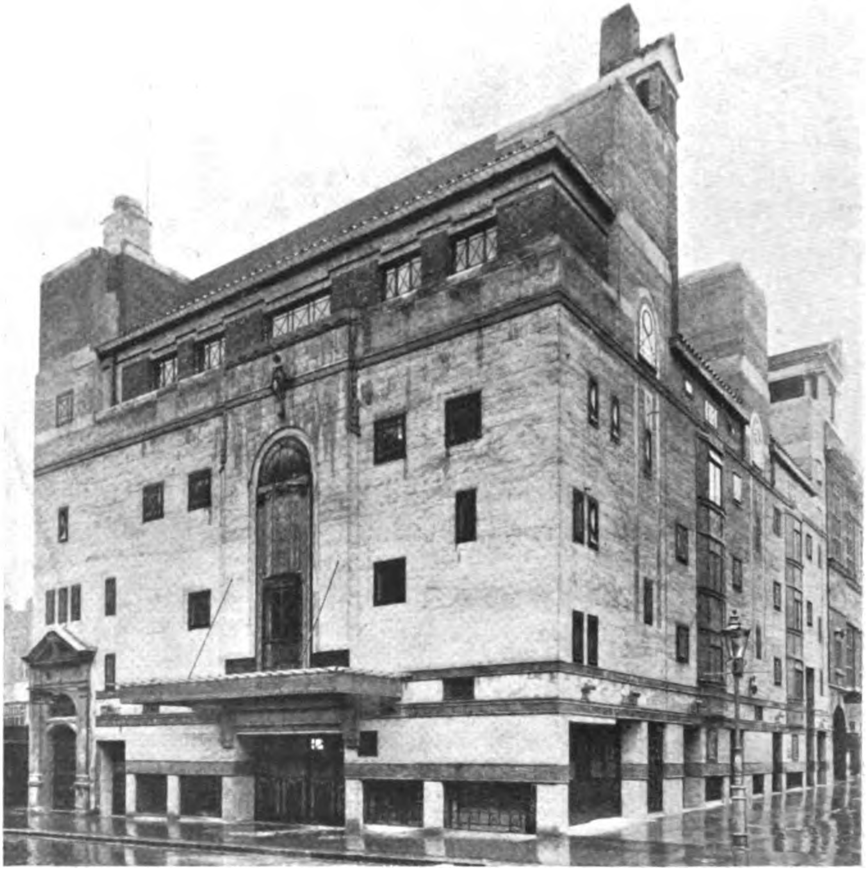
In the Chancery Division recently the Institution of Civil Engineers brought a motion against two consulting engineers for an injunction restraining them and each of them from using, or allowing to be used, after or in connection with their name, or in connection with any profession or business carried on by them, and from printing or writing on any document issued and published by them or either of them the words " Associate Member of the Institution of Civil Engineers " or any letters or words or designation to the same effect.

Mr. Rolt, K.C., and Sir Hugh Fraser appeared for the plaintiffs ; and Mr. E. C. Morey for the defendants.

Mr. Rolt said the subject of the plaintiffs' complaint was that the defendants had employed after the name of one of them the description " A.M.Inst.C.E." in the printed headings of letter paper. That was not justified, and he understood that the defendants were willing to treat the hearing of the motion as the trial of the action, and to submit to a perpetual injunction in terms of the notice of motion and pay the costs.—Mr. Morey said that that was so.

Mr. Justice Tomlin said there would be an order accordingly.

Mr. Morey said that he was instructed to say that the description had been inserted in the headings of a few letters by inadvertence.



[*Mr. E. Schaufelberg, Architect.*

THE "FORTUNE" THEATRE, LONDON. (*See p.* 351.)
A SURFACE-TREATED CONCRETE FAÇADE IN LONDON.

THE "FORTUNE" THEATRE.

A LONDON SURFACE-TREATED CONCRETE FACADE.

In this building the chief point of interest to the structural engineer is the construction of the external walls, which are of concrete mainly 5 in. thick reinforced with a single layer of vertical and horizontal deformed bars (supplied by the Trussed Concrete Steel Co., Ltd.).

The smallness of the site necessitated a choice of construction which would yield the greatest saving in space, and after careful consideration ferro-concrete was decided upon, without any facing of brick or stone. The consequence of this is that actually only 5 in. of ferro-concrete separate the upper circle wall from the building line. The London County Council Regulations demanding at least seven days before centering is struck prevented effective brushing and washing, and the automatic bush-hammer was resorted to. Otherwise, the concrete face would have presented a much more coloured and sparkling appearance, since any tool work on spar or marble has the effect of deadening the refractive value of the material. All windows are made of mild steel, and the frames are set in the face overlapping the concrete, the windows being thus more or less flush with the building line. This saves special reveal work. No attempt has been made to mould the concrete in any way, and the only ornamentation introduced are ribbons of cast lead.

A specially-selected felspar aggregate was used for the outside face, and the surface bush-hammered to expose the pinkish stone. The concrete for the outer face was placed at the same time as the concrete on the inside face, which was made with crushed ballast. The architect has been very successful in his attempt to demonstrate that a concrete external surface can be made very pleasing to the eye, and need not be hidden as is usually done with stone or brick.

The site is so small that every inch is of value, and this made thin walls desirable apart altogether from the saving in the cost of facing stone.

The walls are carried on reinforced concrete columns of rectangular section running from mass concrete foundations below the basement to the top floor level, above which are brick walls and a slab and tiled roof carried on steel frames. The internal framework is of steel (supplied by Messrs. Archibald D. Dawnay & Sons, Ltd., to the designs of Messrs. S. H. White & Son). The steelwork carries reinforced concrete floors to the designs of the Trussed Concrete Steel Co., Ltd.

The problems of the architect were considerably complicated by the necessity for maintaining intact the passageway from Russell Street to the Scottish Church behind. The theatre is both above and below this passage, and the work of underpinning the passage walls was not without its anxious moments; however, "Church and Stage" have again been successfully blended. The underpinning of the thick wall at the back of the stage was fairly simple. The columns against this wall are of reinforced concrete, as it was originally hoped that negotiations with adjoining owners would result in these columns being omitted, but they now extend to the roof and carry the grid floor and the 9-in. wall against the original wall, being quite independent of it.

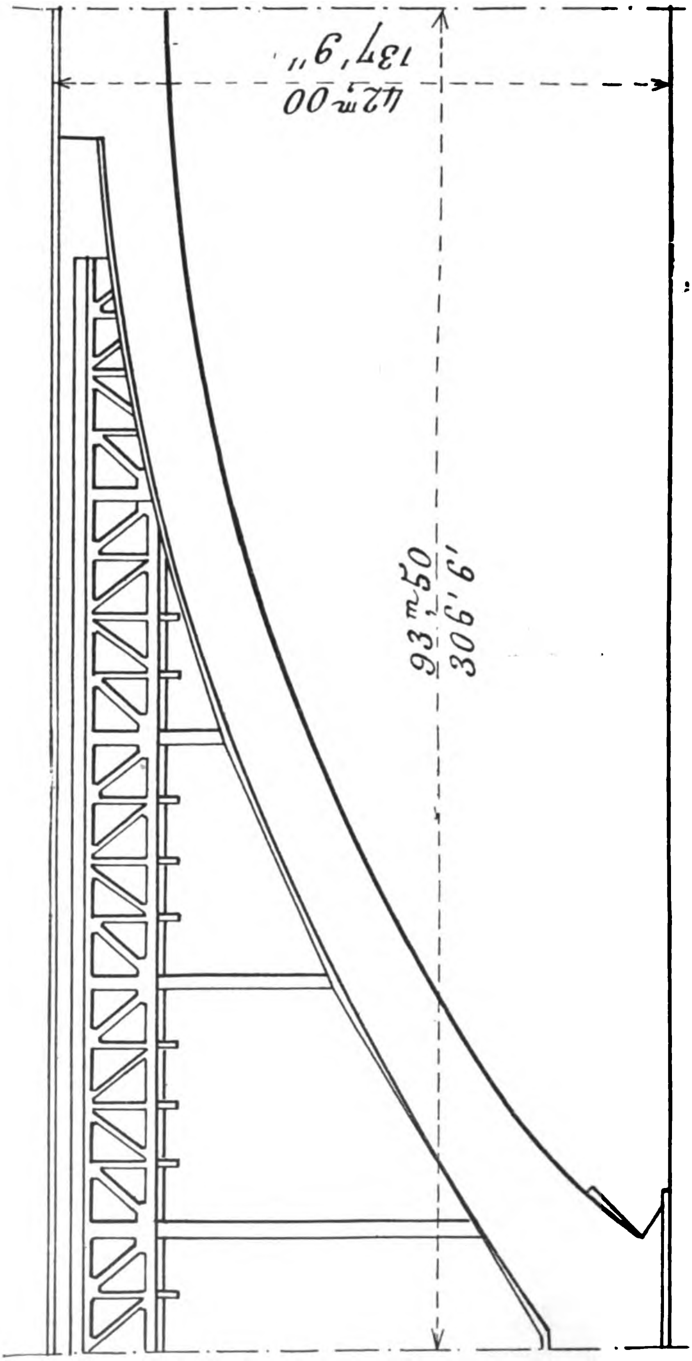
It was originally intended that the roof above the stage should be a light structure offering little resistance to fire on the stage, but later requirements called for a steel frame cased in concrete with a steel and glass lantern.

In addition to the outside walls and columns the framework for the stage wall on the Crown Court side is of reinforced concrete, the dressing-room floors, brick walls, and roof being carried at three levels.

The cantilever retaining wall extending the basement area below the pavement of Russell Street and Crown Court is also of reinforced concrete. It was originally intended to construct the proscenium arch of the same material, but a heavy steel girder carried on reinforced concrete columns was substituted.

The architect is Mr. E. Schaufelberg.

This is the first theatre to be built in London since the war, and its name, "The Fortune," revives the name and memory of the famous house of the same name which formerly stood on the same site and in which Shakespeare acted.



REINFORCED CONCRETE BRIDGE AT ELORN, FRANCE: HALF ELEVATION OF ARCH. (See p. 353.)

REINFORCED CONCRETE BRIDGE WITH ARCHES OF 590 FT. 6 IN. SPAN.

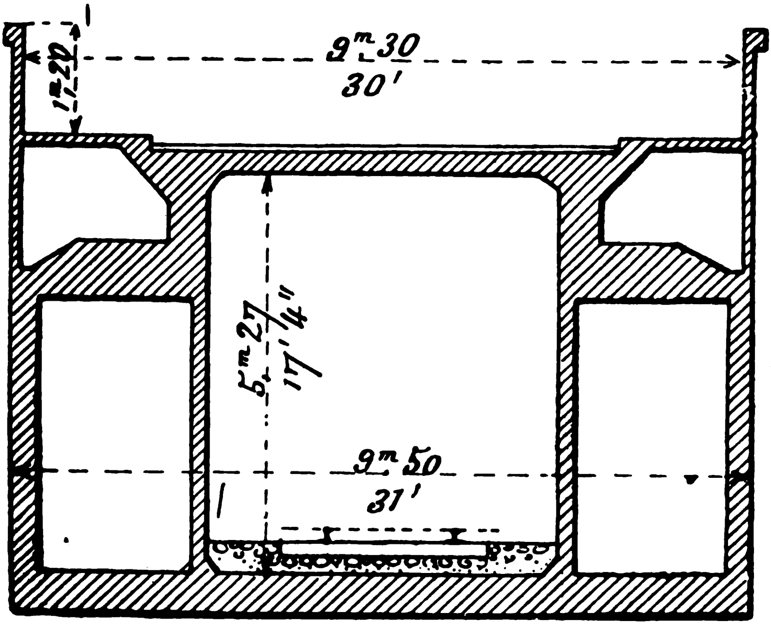
By P. CALFAS, Ing. E.C.P.

The construction of a reinforced concrete viaduct with three main arched bays of particularly large span and dimensions has been recently started across the Elorn near Brest. The arches have a clear span of 590 ft. 6 in. each, and will be the largest of that type existing in the world, being much greater than the 433 ft. span of the St. Pierre-du-Vauvray bridge across the Seine, illustrated and described in our last issue.

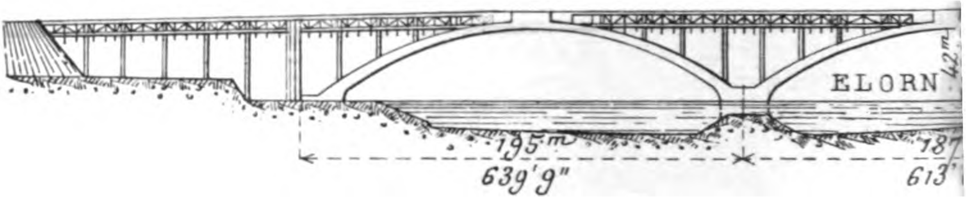
The new bridge is to be built across the estuary of the Elorn between Brest and Daoulas, at a place where the estuary is about half a mile wide, and is to carry over the road from Brest to Sizun and also a single-track railway of normal gauge.

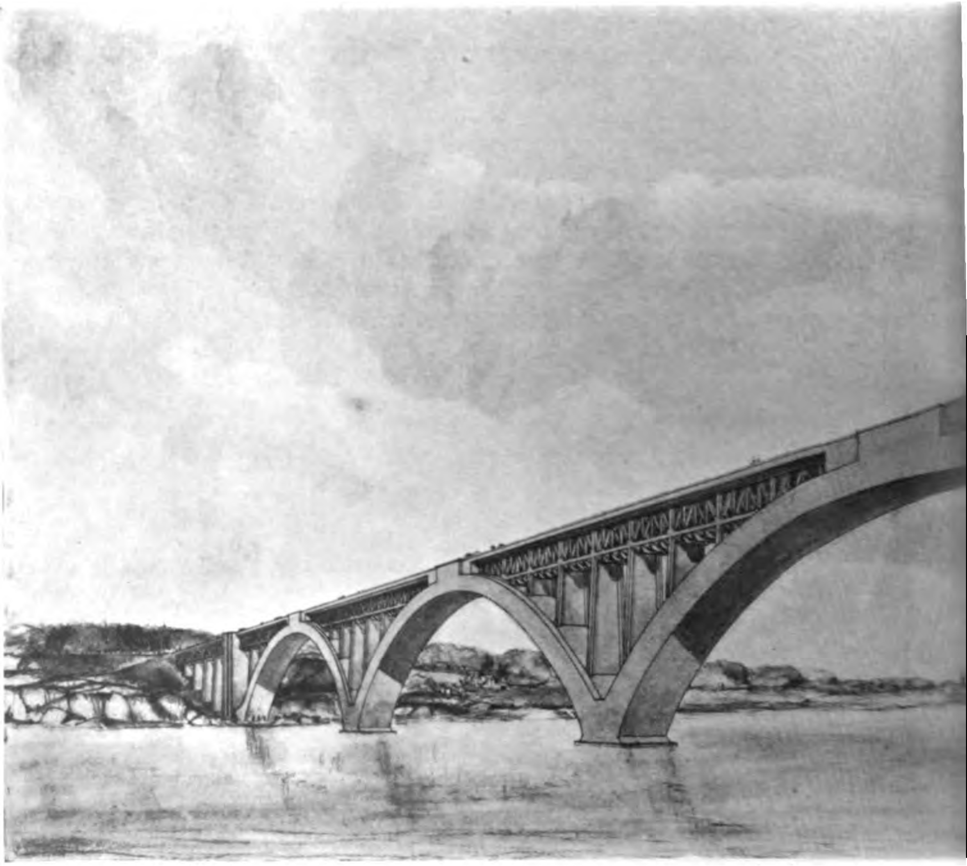
Eight different schemes were submitted for the bridge, three of them for steel bridges, and the remaining five for reinforced concrete. The design of M. Freyssinet, consisting of a double-floor reinforced concrete bridge, and tendered for by M. Limousin, contractor, for a total price of about 11 million francs, was approved and adopted.

The bridge will have a total length of about 2,625 ft. It consists chiefly of three huge reinforced concrete arched bays supported by two piers built in the stream and two abutments on the banks. The top flooring will carry the roadway, and a lower flooring the railway. At each end there will be two separate approach viaducts, one for the roadway and the other for the railway; these viaducts will be 426 ft. 6 in. long each.

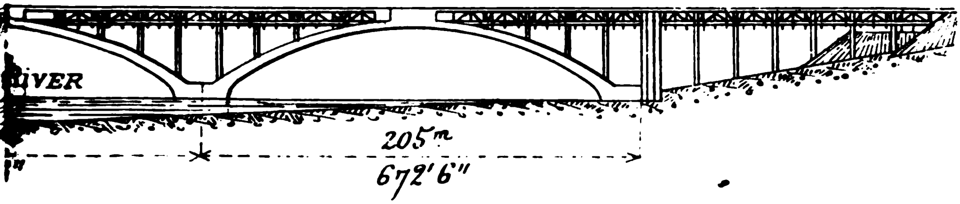


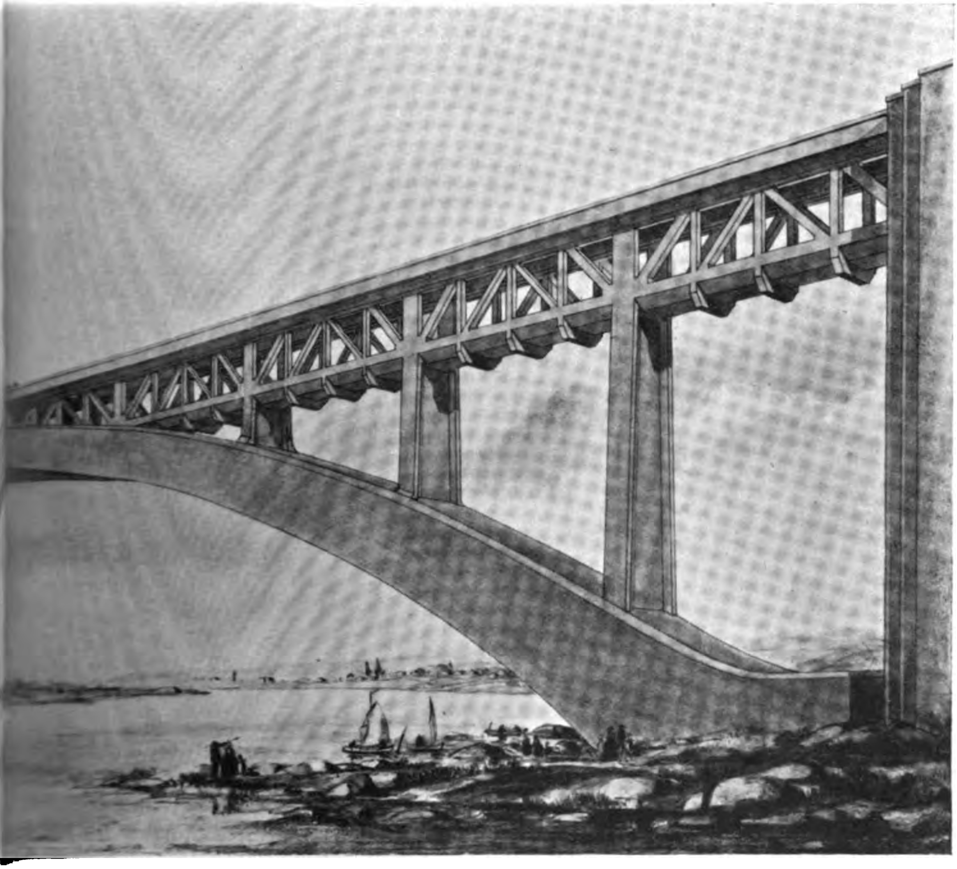
Section at Crown of Arch.





REINFORCED CONCRETE BRIDGE AT ELORN.



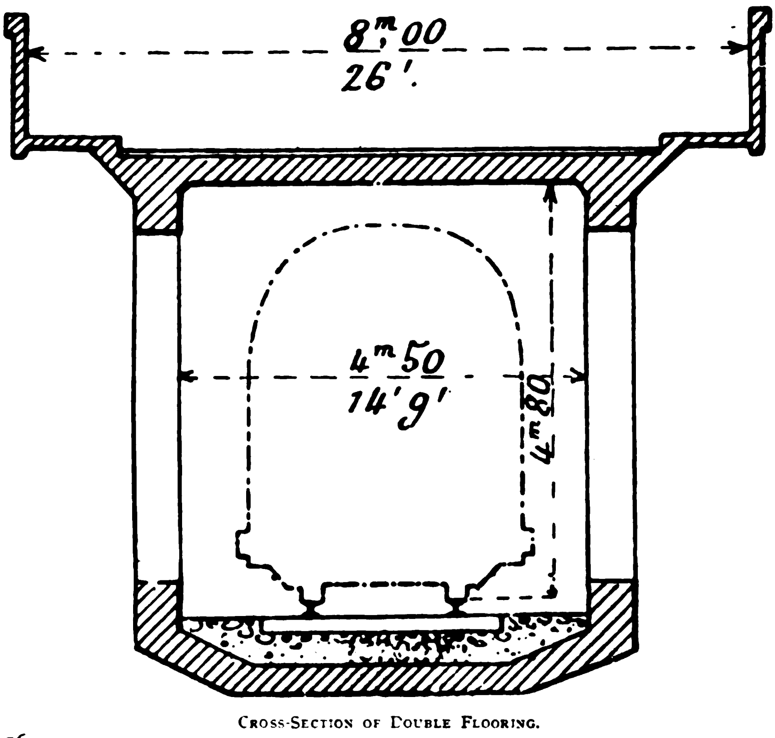


ANCE, WITH ARCHES OF 590 FEET SPAN.

The three main arches are similar; their neutral axis coincides with the funicular polygon of permanent loads according to design. The theoretical span of each of the arches is approximately 590 ft. 6 in., the rise being 108 ft. and the radius of curvature 460 ft. Each bay consists of two tubular hollow arches, rectangular in section. The vertical sides of the arches are comparatively thin, while the arches are thicker. The clear space between the arches is 14 ft. 9 in., so as to allow for the over-all width of the railway rolling-stock. The lower bridge flooring is inserted between the two parallel arches and almost at the level of the crown, the bridge being 31 ft. wide at that point. This double flooring practically represents a rectangular tube or caisson with two vertical latticed sides, the two horizontal sides or floorings carrying respectively the railway and the roadway. The top flooring, intended for carrying the roadway, is extended by corbels 3 ft. 3 in. on both sides so as to allow for two footpaths; the over-all width of the top flooring is therefore 26 ft. 3 in., except above the crown of the arches, where the width reaches approximately 31 ft.

This double flooring is supported by uprights of I-section, three for each half-arch. As it represents a caisson, the double bridge flooring is perfectly rigid and thus allows for a larger space between the supports or uprights to be adopted. Moreover the caisson, owing to its great depth, presents an appearance which is quite in harmony with the general dimensions of the whole work, and particularly with the arches themselves.

The abutments consist of a prolongation of the arches, which become a solid mass instead of hollow. The abutments are built on solid rock, which is



Cross-Section of Double Flooring.

uncovered at the low equinoctial tides, thus facilitating the foundation works.

The piers are to be built on reinforced concrete caissons imbedded in the rock at the bottom of the stream, and have been designed so that they can resist the lateral thrust due to a single arch without it being necessary to build up at the same time the consecutive arch across the other bay; in other words, they constitute abutment piers. A single set of shuttering is to be used for building up consecutively the various arches. The placing of concrete is to be carried out in successive stages.

As no intermediate props for supporting the centre of the arch can be made use of, on account of local conditions, the construction of a "cocked-centre" in the form of a lattice arch to bridge directly over the whole span between the springing of the arches has been contemplated.

The building of the viaduct will require the rise of 26,000 cubic yds. of concrete and 1,200 tons of steel bars for reinforcement.

SCULPTURE IN CONCRETE.

MR. F. DOYLE-JONES, the well-known sculptor, whose concrete "Spirit of the Rocks" was illustrated in our last issue, made some interesting references to the place of concrete in the art of the sculptor in a recent article, in which he said :—

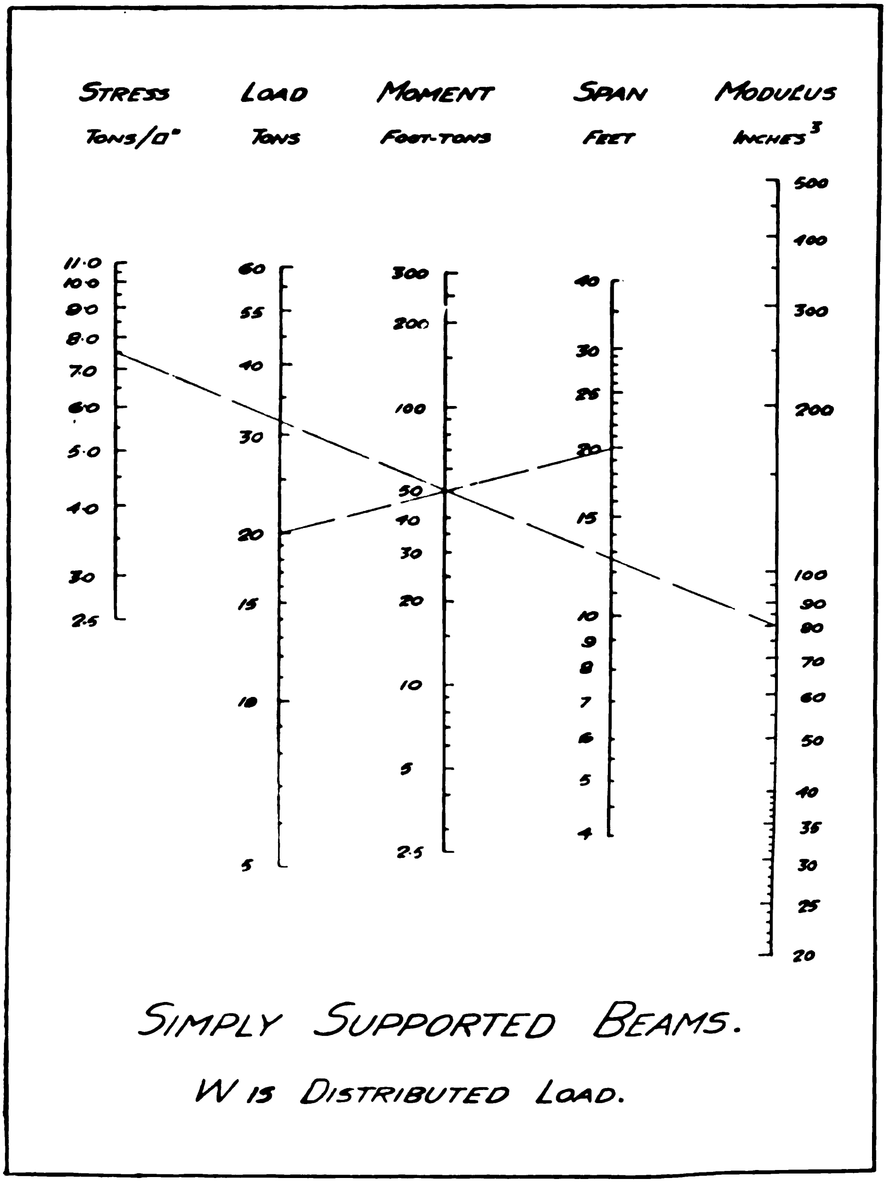
"The Assyrians and the Egyptians, those great masters of the art of colossal rock sculpture, selected granite as the material for their most enduring masterpieces, and in the broad, simple treatment of their gigantic statues they wonderfully exemplified the possibilities and the limitations of this hard and permanent medium of expression. In the march of progress, man to-day is not only using nature's raw materials as he finds them, but, where necessity or new requirements and conditions demand, is doing so with materials in new and varied combinations, after nature's own methods, in the production of synthetic compounds of her native elements.

"The deliberate treatment of the exterior of cast concrete stone is intended to bring out the possibilities of its surface treatment, its granulous texture and vibrant quality, so sympathetic to light under all conditions. One of the most striking and noteworthy features of modern America is the amazing advance of this phase of architecture. On the lines of sound tradition there has grown during the last few years a new and wonderful type of building, born of utilitarian necessities, in an atmosphere of modern business, which might have been considered as the least conducive condition to artistic advance.

"The casting of this material has, by experience in the States, been brought to a high pitch of accomplishment, and for some years now the use of plaster moulds has been superseded by case-hardened sand moulds, on the lines of those used for bronze and metal casting.

"In this country, with its wealth of natural material close at hand, and the absence of any special necessity for rapid expansion or the imitation of native stones, there has been naturally a certain amount of conservatism with regard to the use of concrete or cast stone and granite.

"The general idea of concrete is that of a rather unpleasant material, unresponsive to any fine form and uninteresting in surface texture. This is an idea that slowly but surely is being conquered by the advent of the wonderfully fine products of the recent movement in concrete construction. It is safe to predict that in the next few years we shall see in this country a big development of this movement, and an increasing use of white concrete or cast stone and cast granite as a definitely suitable and adequate material for many different kinds of architectural and sculptural expression."



ALIGNMENT CHART FOR SIMPLY-SUPPORTED BEAMS. (*See p.* 359.)

ALIGNMENT CHART FOR SIMPLY-SUPPORTED BEAMS.

By **CHARLES S. GRAY, B.Sc.Eng.**

THE chart on page 358 will be found useful for calculations relating to steel beams, as it expresses graphically the formulæ—

$$M = \frac{WL}{8}$$

$$\text{and } Z = \frac{M}{F},$$

where W = Total distributed load in tons.
L = Span of beam in feet.
M = Bending moment in foot-tons.
Z = Section modulus in inches^3.
F = Flange stress in tons per sq. in.

Example.—20 tons to be carried over a span of 20 ft. Required section modulus, using a stress of 7·5 tons/sq. in.

(1) Lay a set-square or straight-edge across 20 tons on load line to 20 ft. on span line, reading 50 foot-tons on the moment line.

(2) Lay a straight-edge across 7·5 tons on the stress line and 50 foot-tons on the moment line, reading 80 in.^{3} on the modulus line.

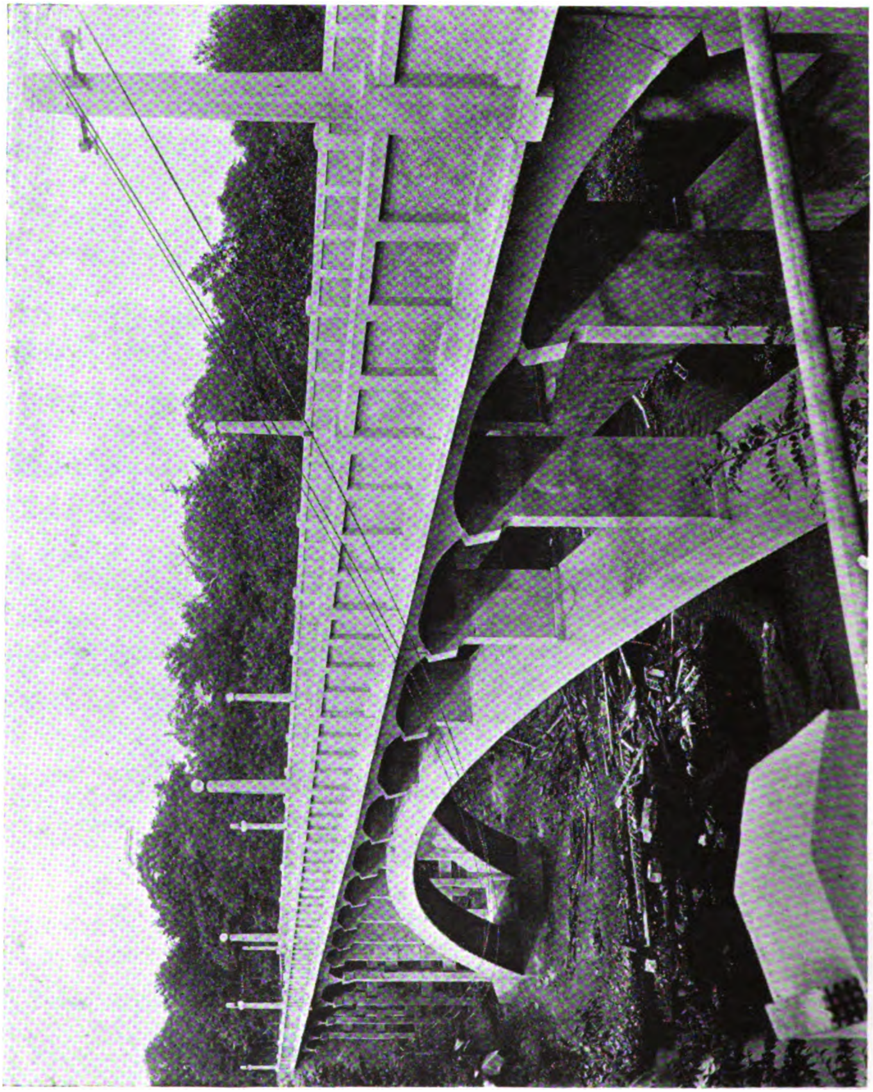
Therefore required modulus = 80 in.^{3}.

The chart can be used for loads other than distributed loads by reducing the load system to an equivalent distributed load, in which connection the following information will be of use :—

Load System.	*Equivalent Distributed Load.*
Load W_1 at centre	$W = 2W_1$
Two loads W_2 at third points	$W = 1{\cdot}78W_2$
Four loads W_4 at fifth points	$W = 3{\cdot}84W_4$
Six loads W_6 at seventh points	$W = 5{\cdot}87W_6$

For all cases where the beam is divided into an even number of divisions (from four upwards) the bending moment is $\frac{WL}{8}$ where W is the load upon the beam.

For use with equations $M = \frac{WL}{10}$ and $M = \frac{WL}{12}$ the results for M and Z obtained from the chart should be multiplied by 0·8 and 0·67 respectively.



REINFORCED CONCRETE BRIDGE BUILT AROUND AN OLD STEEL STRUCTURE AT PULASKI, N.Y. (*See p.* 361.)

BUILDING A REINFORCED CONCRETE BRIDGE AROUND AN OLD STEEL STRUCTURE.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

THERE is at Pulaski, N.Y., U.S.A., a very interesting example of how an old steel arch bridge can be economically replaced by a modern reinforced concrete structure.

The bridge spans a deep ravine, through which flows the Salmon River, the river occupying about half the width of the ravine and the other half being a public park.

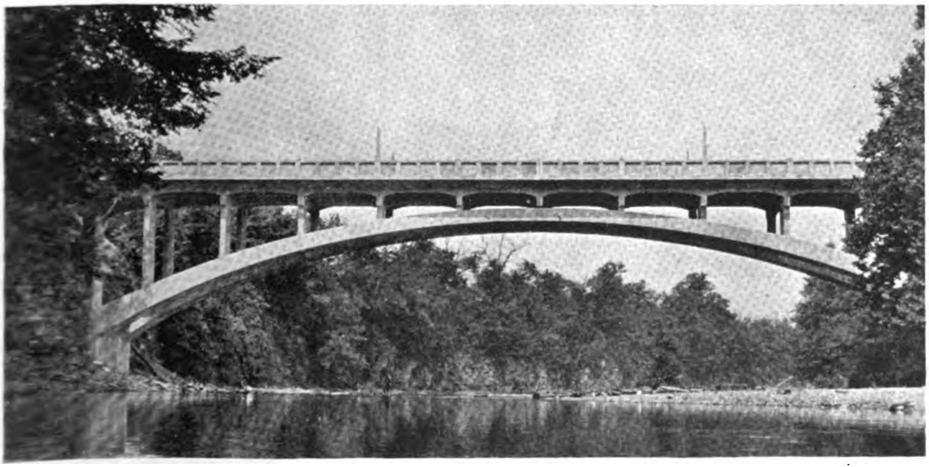
The old structure, built about forty years ago, spanned the river with a two-ribbed three-centred arch of 216 ft. clear span and about 27 ft. rise. Diagonal members supported the top horizontal chords, and the roadway was carried by steel girders at the panel points, on which rested the longitudinal floor beams. The sidewalks were carried by cantilever brackets, riveted to the cross-girders.

From the abutment of the arch to the north side of the ravine the bridge consisted of two 72-ft. span continuous trusses with an 18-ft. cantilever each end, the roadway construction being similar to that over the arch. From the bottom of the river to the roadway was about 40 ft.

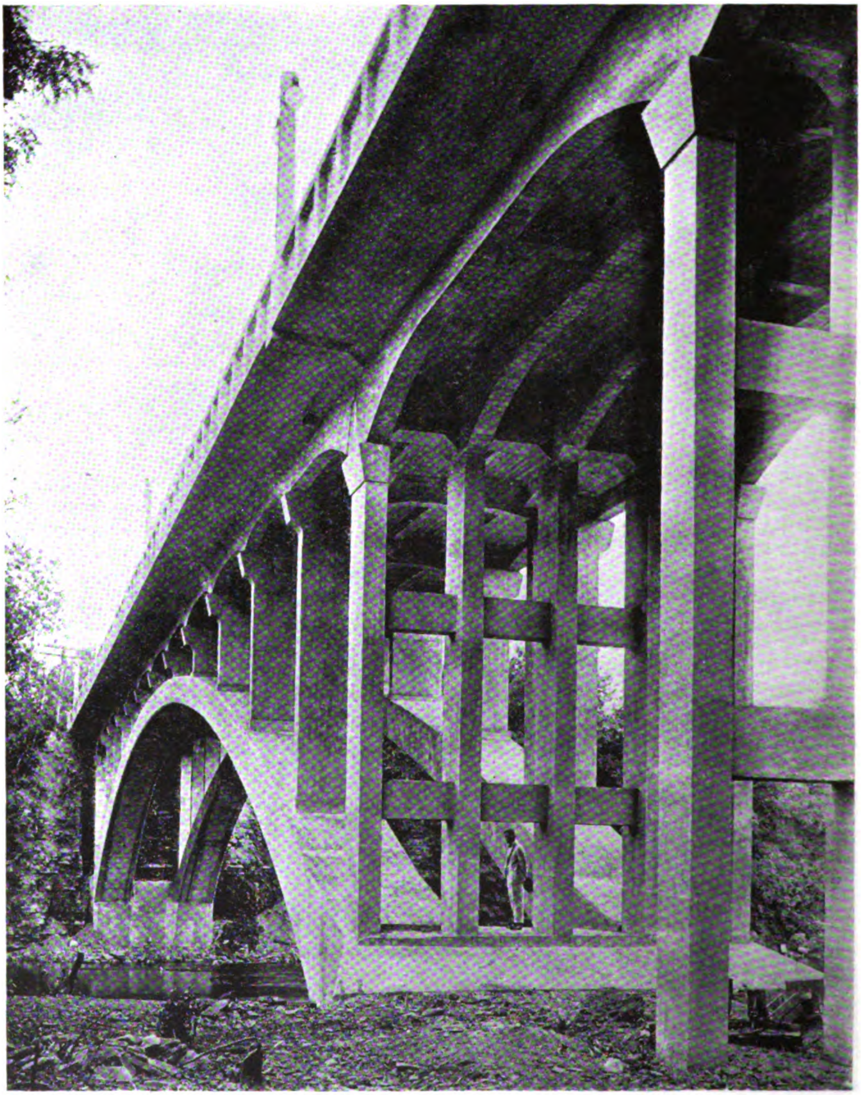
The old steelwork had become considerably worn away, the connections were very poor, and the whole structure was too light for modern traffic. It was therefore condemned, and it was decided to replace it with a modern reinforced concrete structure. The old centre line and grade had to be kept to approximately, but it was not absolutely necessary to maintain traffic during reconstruction.

The consulting engineers considered several alternative designs, but any design departing radically from that of the existing bridge would have meant taking down the old structure before construction could commence. This would have caused loss of time and would have created a difficulty in handling material. With the old bridge out of the way it would have been necessary to build a temporary trestle 30 ft. high and 400 ft. long, or to use a cableway from bank to bank.

If, then, the old bridge could be left in place during reconstruction a considerable saving in cost could be effected, because of the simpler construction problems. The engineers therefore adopted a design conforming as nearly as possible to that of the existing bridge. This design enabled the contractor to use the old bridge as a working platform and for transporting material while the new reinforced concrete bridge was being built around it.



THE BRIDGE COMPLETED.



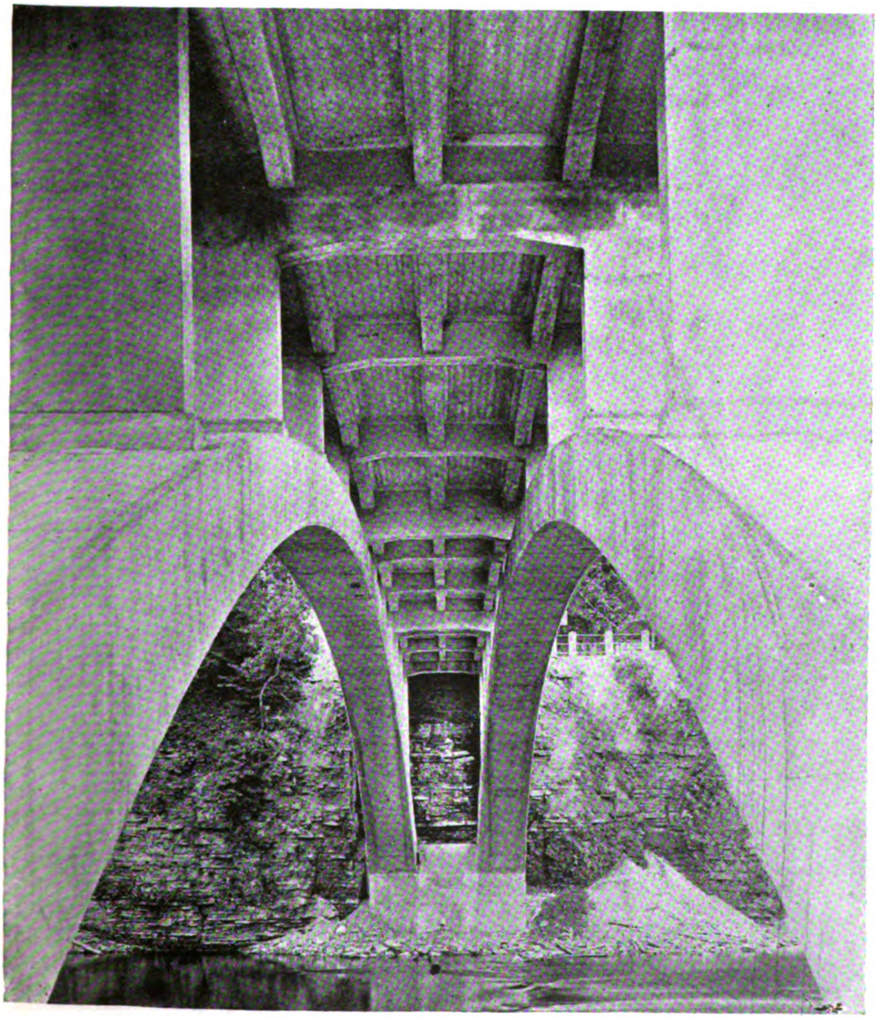
REINFORCED CONCRETE BRIDGE BUILT AROUND AN OLD STEEL STRUCTURE AT PULASKI, N.Y.

The new bridge consists of a two-ribbed open-spandrel arch over the river and a beam-and-girder trestle over the park. The two old steel arch ribs were in fairly good condition, and the abutments were of sound masonry founded on rock.

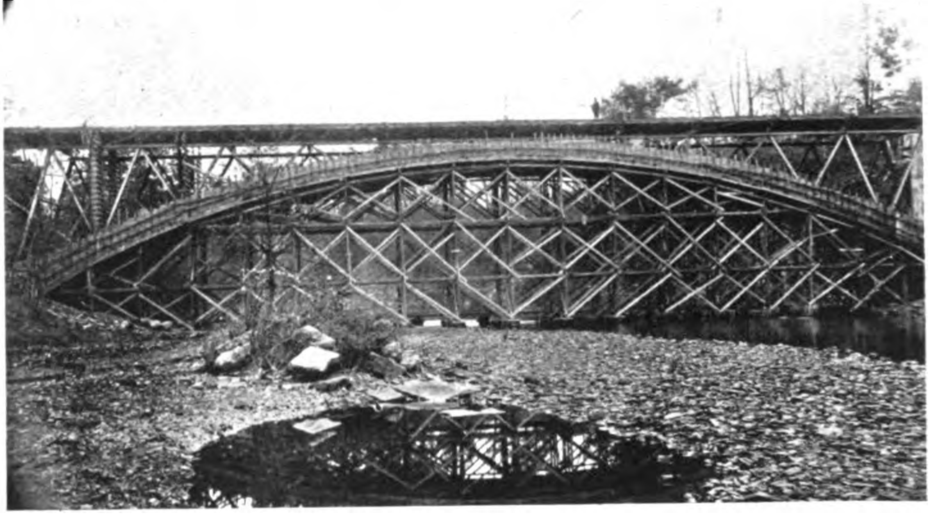
The new arch has a clear span of 200 ft., and a rise of 26·5 ft., that is, a little shorter than the old arch, and the old steel ribs were left embedded in the new reinforced concrete ribs. The old abutments were enclosed in the new ones after being cleaned, and care was taken not to disturb their stability.

At each connection of the old steel diagonal members with the arch ribs a concrete column was erected to carry the floor system. These columns passed through the old top chords, which were boxed in to facilitate their removal afterwards. The columns carried the cross-girders supporting the longitudinal beams and floor slab.

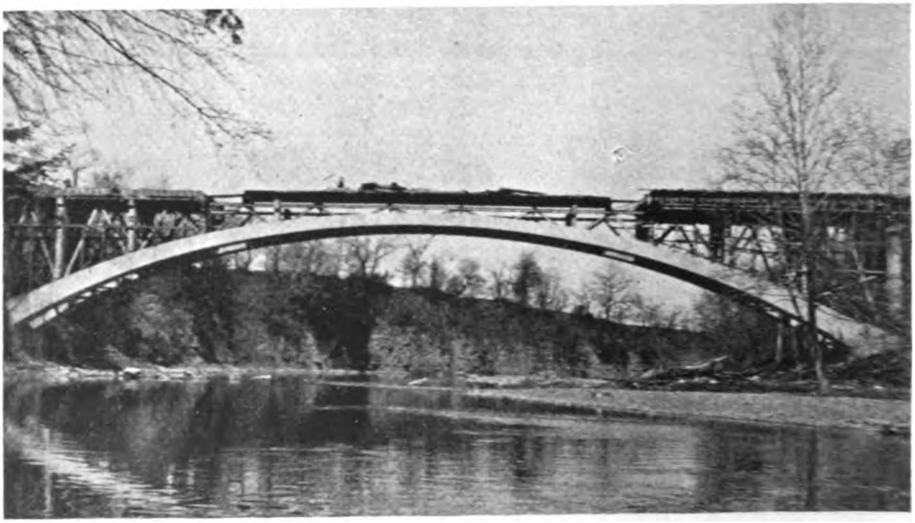
From the arch abutment to the north bank the bridge consists of a concrete



View from Below the Arch.



Showing Concreting of Arch Completed, Forty-nine Days After Starting Work.



Showing New Arch Ribs Completed without Disturbing the Old Bridge.

REINFORCED CONCRETE BRIDGE BUILT AROUND AN OLD STEEL STRUCTURE AT PULASKI, N.Y.

girder trestle of four spans of 36 ft. each. Each bent of the trestle consists of five columns, each one supporting a longitudinal girder. The sidewalks throughout are cantilevered from the outside beams.

The bridge was designed for an uniform live load of 150 lbs. per sq. ft. and a moving load caused by a 20-ton road roller. To the stresses caused by dead and live loads was added the temperature stress due to a rise or fall of 30 deg. F. Each arch rib has a thickness of 3 ft. at the crown and 5 ft. 6 ins. at the springing. Each face of a rib is a parabolic curve symmetrical about the centre line of the rib. The intrados of the rib is a three-centred arc, and the extrados a two-centred arc.

The reinforcement was proportioned to the bending moment, and varies along the rib. Where possible 90 per cent. of the cross-sectional area of the old steel rib was used as effective reinforcing. The spandrel columns, all 15 ins. by 58 ins. in section, are spaced 18 ft. on centre longitudinally. The floor system is divided into four parts by expansion joints, each part consisting of three spans of 18 ft. each. At each expansion joint the cross-girder was dropped so that the beams are free to slide over it.

The roadway is 20 ft. wide and there is a sidewalk 5 ft. wide each side. The sidewalks are simple cantilever slabs, carried by the outside beams, the top part of the beam forming the kerb.

The trestle portion of the bridge is designed as a rigid frame, the five longitudinal beams, each 36-ft. span, being considered as monolithic with the columns, which are fixed at the bases by a massive footing, supporting all five columns of a bent. Each beam is deeply haunched at the columns to provide for the increased bending moment and shear. The columns, being high, are connected with a horizontal strut across each bent midway of their length. The parapet walls consist of pre-cast slabs between plain posts and rail cast *in situ*.

Construction work started on September 5, 1922, and all excavation, foundations and arch ribs were completed by November 5. All this work was done without disturbing the old bridge. By December 15, when it was necessary to close down for the winter, all the spandrel and trestle columns were poured, completing the bridge up to the underside of the deck, and some of the deck forms over the arch were also in place.

The arch centering was much lighter than is usually used for an arch of this size. Each rib was carried independently by post bents, consisting of three 6 in. by 6 in. posts about 4 ft. apart and spaced from 9 ft. to 12 ft. longitudinally, the distance varying so that the posts would be equally loaded. On top of the three posts in a bent was an 8 in. by 10 in. cap, carrying 3 in. by 12 in. joists, supporting 1 in. lagging. The joists were cut to fit the intrados and were notched over the caps.

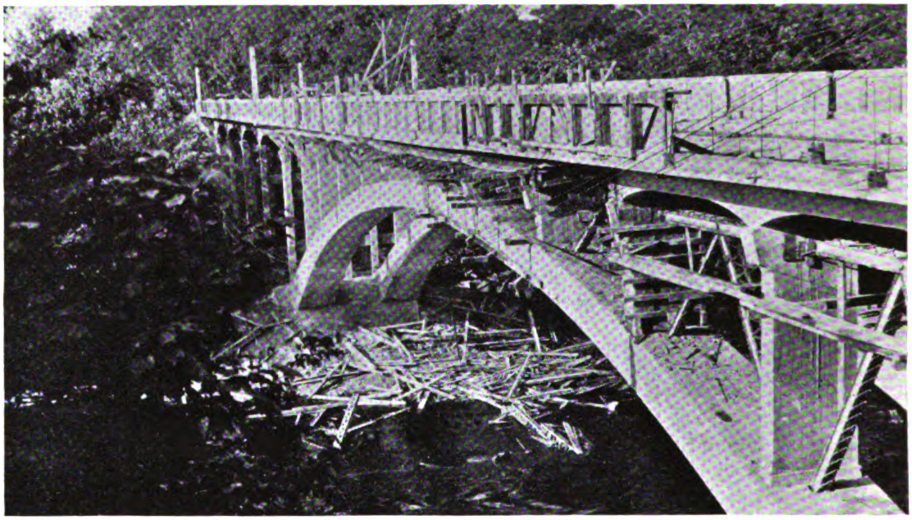
To take the horizontal thrust in the bents, two rows of 6 in. by 6 in. timbers, one at the springing line and one about half-way between springing and crown, were placed on top of the posts and wedged at their ends against the abutments, or, in the case of the upper row, against the caps. These horizontal struts, one to each post in a bent, were carried on 6 in. by 6 in. caps across the bents. The bents for each rib were connected at the top with sway bracing. All longitudinal and cross bracing were 2 in. by 6 in. spruce. The posts of each bent were supported on concrete pedestals about 30 in. wide at the bottom and tapering to the top. The pedestals were 9 ft. long and of sufficient height to bring the top of the concrete just above low-water, the height varying from 1 ft. to 5 ft. Low and high-water was caused by the regulation of the river by a dam farther upstream.

The river bottom was gravel, and the pedestals were proportioned to give a bearing pressure of 1½ tons per sq. ft., this value being assumed from the results of a test on a 2-ft. square block. The forms for the pedestals were placed in the river and weighted down and filled with concrete mixed from gravel dug out of the river.

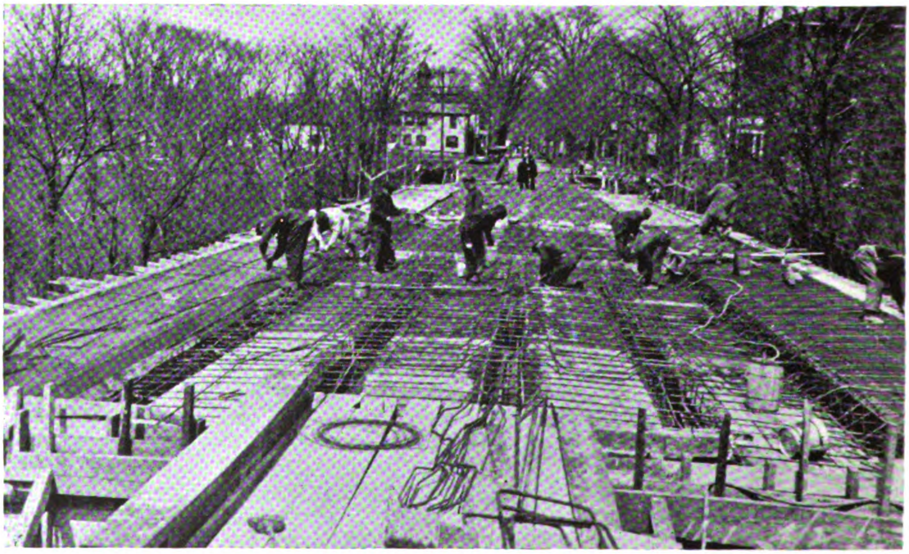
All connections in the centering were made with 20d. nails and not bolted, which was a departure from the usual practice in large arch centres. The nails gave just as good connections as bolts, and were more economical than boring and fitting bolts.

The stripping of the centering after the arch had been poured 28 days occupied only four days with six men, and the method used is interesting. By this time most of the river was frozen.

After the wedges were struck in pairs



ERECTING BALUSTRADE WALLS.



PLACING REINFORCEMENT FOR ROADWAY AND SIDEWALKS.

REINFORCED CONCRETE BRIDGE BUILT AROUND AN OLD STEEL STRUCTURE AT PULASKI, N.Y.

starting from the centre, some of the braces were knocked off. Ropes were passed around the joists and lagging, tying them up to the ribs. Then the bents, two or three at a time, were pulled down bodily by ropes on to the ice, leaving the joists and lagging hanging from the ribs. When all the bents were down, knocked apart, and carried ashore, the ropes around the ribs were lowered and the joists and lagging dropped down on to the ice, a bay at a time. A few of the braces were broken, but the great saving in labour far more than offset the loss of lumber.

After cleaning the lumber was used again in the falsework for the trestle portion. All lumber, except the braces, was long-leaf yellow pine, the braces being spruce. The centering was particularly successful, as the settlement at the crown due to pouring was less than ½ in., although there were six joints in bearing across the grain.

Each rib was poured in three equal volume sections each side of the crown with keys at the crown and abutments. A section each side of the crown was poured first, then the sections near the abutments, and last the quarter-point sections, both ribs being poured together. All the keys were poured simultaneously some days later. By this method of pouring the effect of contraction was minimised.

The roadway system over the arch is split into four sections by expansion joints ; each section was therefore independent of the others. The two haunch sections were poured first in order to load the arch ribs symmetrically ; then the two crown sections were poured. Only sufficient of the old bridge floor was torn out at a time to enable the forms for a section to be built, so that there was always a solid deck throughout the bridge to work from.

The old steel beams and the old top chords of the arch were used to support the formwork, and when done with were dropped into the river and hauled out on to the bank with teams.

The roadway of the trestle portion had no expansion joint between the bent over the abutment and the end of the bridge, so that these forms were built all together, the old deck being taken up in advance of the forms. As these forms were about 25 ft. above the ground, post bents on mud-sills were used to support them.

The precast slabs for the parapets were made in the winter in a shed, constructed of form panels built up ready to use in the spring. The shed enclosed the boiler, and steam-pipes were put in to keep it at a constant temperature. Only two men worked all winter, and six to eight panels per day were finished. The panels were 3 ft. 9 in. long by 2 ft. 6 in. wide and 2½ in. thick, reinforced with wire mesh. On the bottom of the forms was spread about ¾ in. of lake gravel and cement mixed fairly dry, then about 1 in. of wetter concrete and the mesh reinforcing, and finally a top coat similar to the bottom. All material was mixed with hot water. The panels were cured in steam for 24 hours and were then taken out of the forms. Each face was immediately brushed with a wire brush and water, taking off the top film of cement and leaving the gravel aggregate exposed, afterwards washing down with water. This was a very economical process, and gave a very pleasing effect to the panels. The rough texture and the different colours of the gravel stand out in sharp contrast to the rubbed concrete posts and rail around them.

The parapet posts and rail were built in sections between expansion joints, the forms being built around the pre-cast panels. The lamp-posts were cast in place and the panels bush-hammered.

After the roadway slab was finished it was waterproofed with one layer of a cotton fabric impregnated with asphalte and laid in hot asphalte. The fabric was carried 4 in. up the kerbs and turned over into grooves left in the concrete. On top of the waterproofing was laid the 4-in. concrete wearing surface with ⅜-in. expansion joints about every 30 ft. The contour of the roadway was a parabola with a rise of 3 in. The sidewalk finish of 1 in. of one of cement to two of sand was put on monolithic with the rough slab and broom finished.

The concrete mixture throughout was one part cement, two parts sand, and four parts crushed limestone, except for the abutments which were 1 : 3 : 6 and the parapet rail which was mixed 1 : 1½ : 3.

All exposed surfaces were rubbed down, as soon after stripping as possible, with a carborundum brick and water in which there was a little cement.

When the bridge was nearly finished all

the steel of the old bridge protruding from the concrete was cut off with a portable oxy-acetylene cutting outfit. A small box or bag had been left around each piece of steel left in the concrete, so that it could be cut off an inch or two within the concrete, and this was afterwards patched.

The mixing plant was placed at one end of the bridge and all concrete was wheeled in buggies, holding 6 cu. ft., along the old bridge to the place required.

To deposit the concrete in all places below the level of the old bridge roadway, elephant trunk chutes were used. These chutes were made in sections of galvanised iron 4 ft. long, 10 in. diameter at the top and 9 in. at the bottom. The wider end slipped over the smaller and was held by chains and hooks. The top section was fitted with a hopper into which the buggies were emptied. These flexible chutes, used in lengths from 10 ft. to 50 ft., were very convenient, as they could be lengthened or shortened very quickly and the lower end swung to any desired point.

Temperature changes were provided for by five expansion joints, one at the crown, one at each quarter-point, and one at each abutment, extending completely through the road beams and slabs. Horizontal sliding joints were formed by trowelling the concrete smooth and covering with two layers of tar-paper. Vertical joints were filled with ½ in. thick pre-moulded expansion joint-filler of asphaltic felt.

The road surface was drained by rectangular cast-iron boxes placed in the curbs every 30 ft.

Electric lighting wires were carried in fibre conduits placed in the parapet rails before pouring. Each lamp-post was provided with a service-box covered with a bronze plate, and surmounted with a bronze casting to carry the globes.

A minimum of plant was required for the construction of the bridge. A ¾-cu. yd. mixer, boiler, concrete buggies, and acetylene cutting outfit was all the plant required.

After the winter, work was resumed about the middle of March and the bridge was opened for traffic on July 10.

The bridge was designed and supervised by the Concrete Steel Engineering Co., of New York, and built by G. W. Thompson, engineer and contractor, of Syracuse, N.Y., the contract price being about £16,000.

A STUDY OF LOADING TESTS ON REINFORCED CONCRETE STRUCTURES.

By **EWART S. ANDREWS, B.Sc., A.M.Inst.C.E., M.I.Struct.E.**

(1) A TWO-WAY HOLLOW TILE FLOOR.

INTRODUCTORY.

DURING the past twenty years a large number of tests upon reinforced concrete structures have been made by experimental engineers, who have published their results with very full particulars of the deflections and stresses resulting from their records. The resulting papers often, however, require a very considerable amount of study in order to extract from them simple rules to guide us in our design. The result is that practical designers, even if they see the publications, are not able to find time to study the papers at sufficient length.

The aim of the present articles is to consider some of the more prominent tests and to study their principal results in the light of ordinary methods of design, explaining at greater length than is usually considered desirable in scientific papers how we may interpret the results. The writer will endeavour to distinguish clearly between the facts given by the authors of the papers and the conclusions at which he arrives from their results.

GENERAL PARTICULARS OF THE FLOOR TESTED.

The tests which we are about to study are recorded in Technological Paper No. 220 of the United States Bureau of Standards and are by Messrs. W. H. Slater, A. Hagener and C. P. Anthes.

The concrete was of 1 : 2 : 4 mix, the coarse aggregate being gravel from ¼ in. to 1 in.; test results in compression gave 2,030 lbs. per sq. in. at 35 days and 2,980 lbs. per sq. in. at 115 days.

The tests were made on a large expanse of floor the plan of which is shown in *Fig.* 1; the floor slabs were formed of hollow clay tiles 12 in. broad and 6 in. deep; a reinforced concrete slab 4 in. wide being cast between the tiles in each direction.

The reinforcement consisted of ½-in. round bars made of steel having an average yield point of 53,560 lbs. (23·9 tons) per sq. in. and an ultimate strength of 87,220 lbs. (38·9 tons) per sq. in. We may note in passing that this steel is stronger than would be allowed under the London County Council Regulations. *Fig.* 2 shows a section of the floor. The bottom reinforcement went right across the span and the top reinforcement extended to one-fifth of the span on each side of the beams, and was hooked at the ends.

From *Fig.* 1 it will be seen that there were in all eighteen panels. Six were square panels of 16 ft. side, six were rectangular panels 19·25 ft. by 16 ft. $\left(\frac{l}{b} = 1{\cdot}2\right)$, and the remaining six were rectangular panels 22·5 ft. by 16 ft. $\left(\frac{l}{b} = 1{\cdot}4\right)$; there were also three cantilever portions shown at the top of the plan.

The panels were carried by reinforced concrete beams of breadth practically 12 in., so that clear spans of the slabs were 1 ft. less than the distances shown on *Fig.* 1.

DESIGN LOADS UPON FLOOR.

We will first calculate according to the usual or orthodox methods of calculation the safe or design load for this floor, noting that the weight of the floor slab itself was 50 lbs. per sq. ft.

Take first the case of the square panels ; these being all end panels the bending moment at supports and intermediate points would be taken as $\frac{Wl}{10}$ without allowing for the reinforcement running both ways. For a square panel the usual method allows the bending moment in each direction to be halved, so that we have to provide for a B.M $= \frac{Wl}{20}$.

The area of a $\frac{1}{2}$-in. φ bar $= 0{\cdot}196$ sq. in., and the effective depth is $5{\cdot}25$ and breadth $= 4$ in.

$$\therefore \text{Reinforcement ratio} = \frac{A}{bd} = \frac{0{\cdot}196}{4 \times 5{\cdot}25} = 0{\cdot}0093$$

Taking $t = 16{,}000$ and reading from the usual diagram for rectangular beams we have the following approximate results :

$$\begin{aligned} \text{Safe bending moment B} &= 108\ bd^2 \text{ for concrete at } 600 \\ &= 130\ bd^2 \text{ for concrete at } 730. \end{aligned}$$

As the tile must have the effect of adding to the strength of the concrete and give, in part at least, a T-beam action, we will take $B = 130\ bd^2$ as the design bending moment for this floor on orthodox theory.

In one case $b = 4$ and $d = 5.25$.

$$\begin{aligned} \therefore \text{B} &= 130 \times 4 \times 5{\cdot}25^2 \\ &= 14{,}300 \text{ lb.-in.} \end{aligned}$$

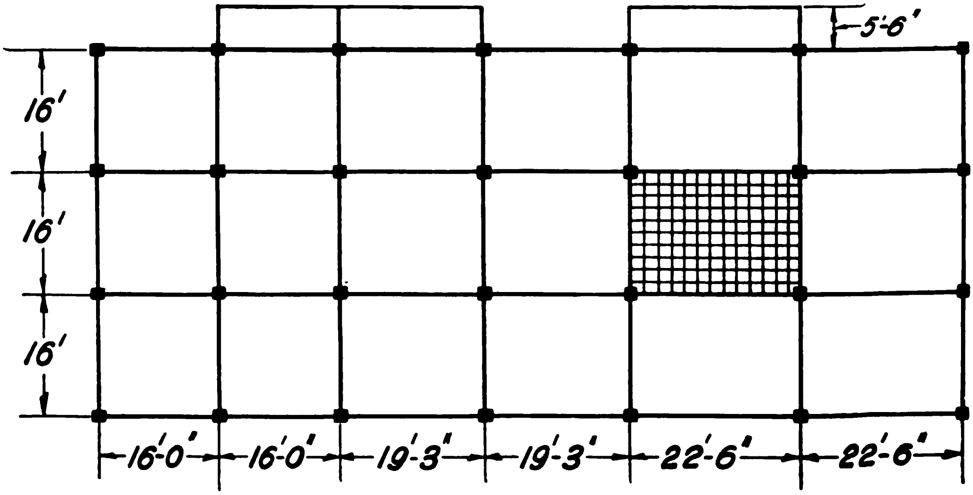


FIG. 1. PLAN OF FLOOR TESTED.

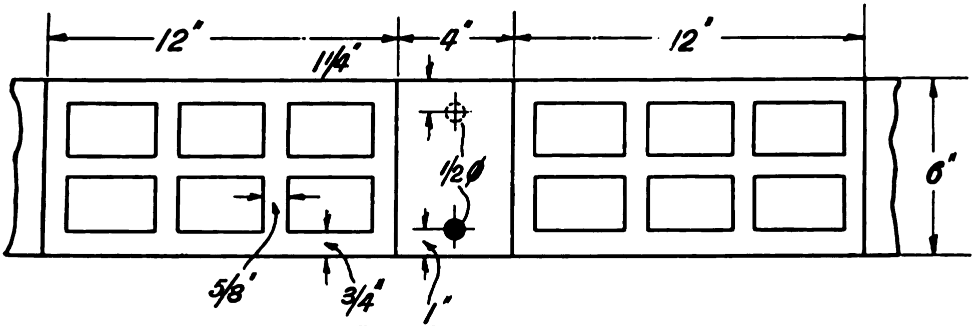


Fig. 2. Section of Floor.

If w is the inclusive load per square foot of floor area, we note that each beam carries a width of floor 16 in. wide and the span is 16 ft.

$$\therefore W = \frac{w \times 16 \times 16}{12}$$

$$\text{and } B = \frac{Wl}{20} = \frac{w \times 16 \times 16 \times 16 \times 12}{12 \times 20}$$

$$= 205\, w \text{ lb.-in.}$$

$$\therefore w = \frac{14{,}300}{205}$$

$$= 69{\cdot}8 \text{ lbs. per sq. ft.}$$

For the other two panels for which $\frac{l}{b} = 1{\cdot}2$ and $1{\cdot}4$ we have the coefficients of reduction on the Grashof-Rankine theory specified by the L.C.C. equal to 0·67 and 0·79 respectively, instead of 0·5 for the square panel; these figures give $B = 273\, w$ and $324\, w$ respectively, from which the loads come 52·2 and 44·2 lbs. per sq. ft.

From this we see that the design values for the inclusive loads on the three sizes of panel according to our usual method of calculation were 69·8, 52·2 and 44·2 lbs. per sq. ft.

The authors state that the corresponding values in accordance with the U.S.A. Joint Conference report were 83, 67 and 48 lbs. per sq. ft.

Loading Test Results.

The loading tests were started when the concreting had been completed for just over two months and were first spread uniformly over the various panels, the intensity being greatest on the square panels. By means of strain gauges the actual stresses in the steel and concrete were measured at various loads.

Uniform loading was continued until the inclusive loading on the three sizes of panel were 447, 330 and 280 lbs. per sq. ft., and no sign of failure was visible. On our figures for the design load, these test loads are about 6·4 times the design load.

The load was applied in the form of stacks of bricks, and in order to obviate

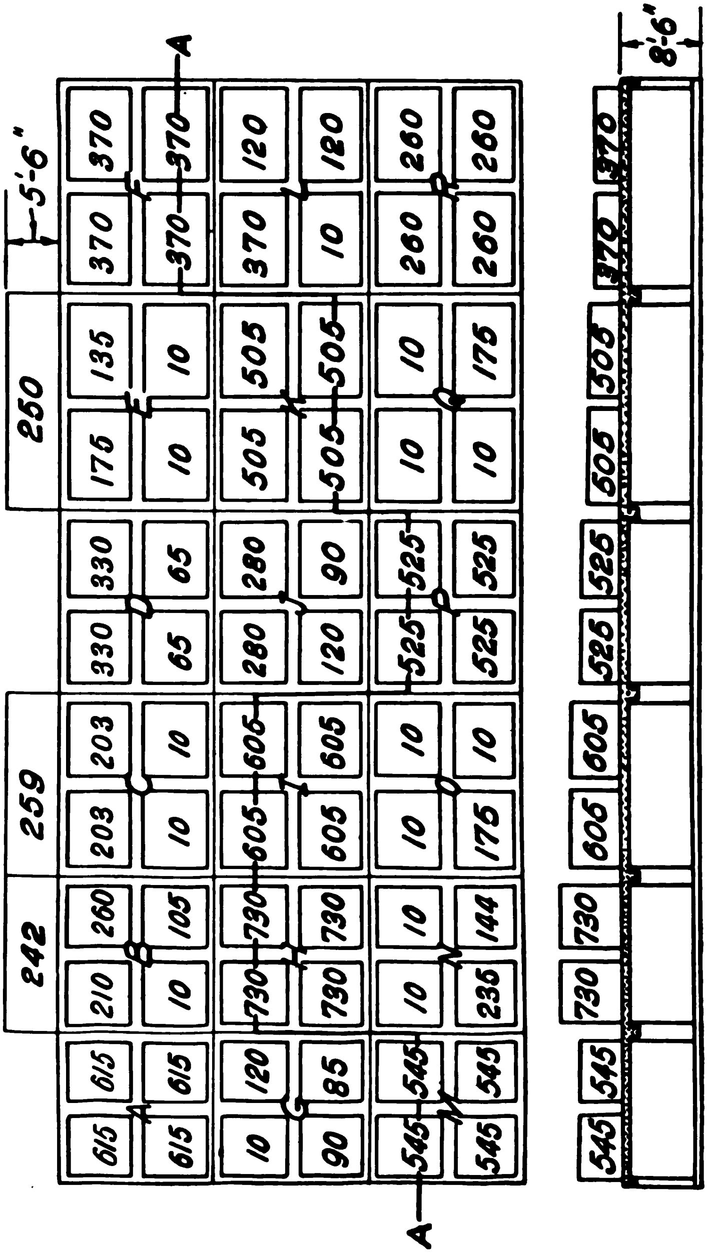


Fig. 3. Diagram of Load Intensity on Floor.

" arching " action aisles 18 in. wide were left over each girder and along the centre line of each panel in both directions. The uniformly distributed load was assumed to be equal to the total load on the panel divided by the product of the clear spans.

After the uniformly distributed load indicated above had remained in position, the loading was shifted so as to give much heavier loads on some panels. *Fig.* 3 represents the distribution of loading from April to November, the lower portion of the figure representing a section along the staggered line AA ; it should be remembered that the loads marked on this figure are superimposed loads in pounds per square foot and that we have to add 50 lbs. per sq. ft. for the dead load of the floor to obtain the inclusive load.

The loads were later further concentrated on the internal panels H, J, K to an intensity of 1,413, 1,184 and 920 lbs. per sq. ft. respectively, and these remarkably high loads were sustained for one year without failure.

FAILURE LOAD ON CORNER PANEL.

In order to avoid damage in case of failure struts had been arranged at intervals below the floor slab, the tops of the struts being 3 in. below the under-sides of the slabs. With the loading indicated in *Fig.* 3 the corner panel F gradually settled down on to the struts so that we may regard the ultimate load on that panel as 370 + 50 = 420 lbs. per sq. ft. ; this is 9·5 times the inclusive design load of 44·2 lbs. per sq. ft. for this panel.

It will be useful to consider the stresses in the material on the assumption that the ordinary theory holds up to the ultimate load.

We have previously seen that taking $\frac{Wl}{10}$ as the maximum bending moment, and adopting the Grashof-Rankine coefficients for rectangular slab effect, the maximum bending moment on this panel is given by

$$\begin{aligned} B &= 324\ w \text{ lb.-in.} \\ &= 324 \times 420 \\ &= 136{,}000 \text{ lb.-in.} \end{aligned}$$

The effective length is 5·25 in. and the lever arm a will be about 4·7 in., so that as the area A of the steel is 0·196 sq. in. we should have

$$\begin{aligned} \text{stress in steel} = t = \frac{B}{Aa} &= \frac{136{,}000}{4{\cdot}7 \times {\cdot}196} \\ &= 148{,}000 \text{ lbs. per sq. in.} \end{aligned}$$

The ultimate strength of the steel employed was 87,220 lbs. per sq. in., so it is clear that the bending moment which we have assumed is considerably higher than that which was developed in practice.

In a paper on " The Strength of Rectangular Slabs " read before the Institution of Structural Engineers and appearing in " Concrete and Constructional Engineering " for January, 1923, Mr. A. Ingerslev, B.Sc., explains a method of treatment of the stresses in rectangular slabs supported upon four edges which is based upon the behaviour of such slabs on failure and gives results differing widely from those given by the Grashof-Rankine theory.

According to Mr. Ingerslev's coefficients, for $\frac{l}{b} = 1{\cdot}4$ the strength of the slab supported about four edges is 2·23 times as strong as the same slab supported about two edges only.

Taking as before $\frac{Wl}{10}$ as the value of the maximum bending moment in the slab, and neglecting "slab action," we shall have in our case

$$B = \frac{Wl}{2{\cdot}23 \times 10} = \frac{w \times 16 \times 16 \times 16 \times 12}{2{\cdot}23 \times 12}$$
$$= 184\, w \text{ lb. in.}$$
$$= 184 \times 420$$
$$= 77{,}300 \text{ lb. in.}$$

According to this theory, therefore, we shall have

$$\text{Stress in steel} = t = \frac{77{,}300}{4{\cdot}7 \times 0{\cdot}196}$$
$$= 84{,}000 \text{ lbs. per sq. in.}$$

This is just below the ultimate strength of the steel, and shows that calculations based upon Mr. Ingerslev's figures for the ultimate strength of the steel give a very close result to that found as a result of the tests under consideration.

General Results of Strain Measurements.

By means of strain gauges and deflectometers the strain in the tiles, concrete, and steel were measured at a number of points under various loads, and deflections of the slab were measured at a number of points; from the strains, the stresses in the material were computed. The following summary gives some of the more interesting of these measurements.

(*a*) Deformations in the tiles were on the average 70 per cent. as great as those in the adjacent concrete, but the compressive stresses in the tiles were probably equal to or greater than those in the concrete. The ultimate compressive strength of the tiles tested on end was 4,920 lbs. per sq. in.

(*b*) The walls of the tiles in contact with the concrete ribs appear to have resisted shearing stresses equally with the concrete.

(*c*) The average negative B.M. for exterior panels was 20 per cent. greater than that for interior panels for like sizes.

(*d*) The average positive B.M. for exterior panels for uniform loading was 25 per cent. greater than that for interior panels.

(*e*) The average distance from the supports to the point of zero stress in the top reinforcement was less than one-fifth of the span.

(*f*) The average negative bending moment for interior spans, as determined from stress measurements, were $\frac{Wl}{54}$, $\frac{Wl}{36}$ and $\frac{Wl}{25}$ for the square, intermediate, and long panels respectively.

(*g*) For inclusive loads of 325, 280, and 225 lbs. per sq. ft. on square, intermediate, and long panels respectively, the deflection at the centre of the panels was about $\frac{1}{900}$ of the span. It will be noted that these loads are about five times those that we have computed as the "design" loads.

GENERAL DEDUCTIONS FOR USE IN DESIGN.

We think that the following facts can be deduced from the above tests:

(1) That if designed upon the orthodox methods floors of this type give a factor of safety considerably in excess of the figure 4 which is usually regarded as adequate.

(2) That for the corner panel which failed the factor of safety based upon the "design" load was 9·5 measured upon the inclusive load.

(3) That interior panels carried for one year without failure *twenty times* the inclusive design load as computed by orthodox theory.

(4) That the slab coefficients recommended by Mr. Ingerslev can safely be adopted in design.

ECONOMICS IN CONCRETE.

THE results of some experiments he had carried out during last year on concrete mixtures were given by Mr. B. Price Davies, F.S.I., at the last meeting of the Institution of Structural Engineers.

The results of the experiments are given in the tables on pp. 377 and 378. The ratios are given numbers ranging from 1 to 36, and these ratios are further dealt with for four different classes of aggregates. These aggregates are classified as A, B, C and D, and there are therefore a total of 144 mixtures. Each mixture is given its own group of figures in two or three lines.

The first line gives the volumes in cubic yards for the cement, sand, and stone required to make one cubic yard of consolidated concrete. The first figures of the second line of each group give the comparative total weights of the mixtures, and are therefore comparative densities, and are preceded in each case by the letter " D " in order to facilitate reference.

The second items in the second lines of each group give the comparative costs of the mixtures, and are preceded by the symbol of money-pounds, namely " £."

The third items in the second lines, preceded in each case by a " V " give the results of Messrs. Taylor and Thompson compared with those of the lecturer.

When making practical experiments to find the volumes of the constituents, briquettes were made of mixtures when these were sufficiently fat for the purpose, and the third lines of the groups where they occur are in connection with tests made with these briquettes.

The first items of the third lines give the comparative tensile strength of the mixtures in lbs. per square inch, and are designated accordingly.

The second items in the third lines give the comparative absorption in the briquettes, the results being in grammes, and distinguished by " G."

The third items, in the third lines, preceded by " W," are the comparative results of wear.

The specific gravity of the cement used was 3·164, and the fineness as follows :—

On 76 × 76 sieve, a residue of 0·4 per cent.

On 180 × 180 sieve, a residue of 9·5 per cent.

Filled lightly into a measure, the cement was found to weigh 80 lbs. per cu. ft., and by shaking the measure the weight was increased to 90 lbs. per cu. ft. The former basis was adopted for these experiments, and in actual practice the variation is usually between these two figures.

On a basis of filling the dry cement to 80 lbs. per cu. ft., this particular cement contracted to 0·75 of its original dry volume when mixed with water and made into a cement paste. Previous experiments with another make of cement gave a result of 0·85, when the dry cement was based on the 90 lbs. basis. On the 80 lbs. basis, this would also be practically 0·75, and the results, therefore, coincide with each other as well as with those under discussion when dealt with in connection with Dr. Faber's paper read at the Institution last year.

With the specific gravity at 3·164, the weight of the solid content of the grains of cement is 197 lbs. per cu. ft. Taking the weight of cement powder at 80 lbs. per cu. ft., this allows a percentage of voids of 59 per cent.

If again the cement at 80 lbs. per cu. ft. contracts to 75 per cent. of its dry state when mixed with water, then (on the basis of its volume as dry powder) there would be in the neat cement concrete a percentage of voids of 75 per cent. minus 41 per cent., or 34 per cent.

On the basis of the volume of the neat cement concrete being 100 per cent., the percentage of voids would resolve itself into 25·5 per cent.

In dealing with this aspect of the subject, it must be borne in mind that, apart from the chemical combination of water with cement, there is a possibility of the grains of cement expanding. In view of such possibilities, the voids in cement powder are taken as 50 per cent. for the purposes of this paper.

The sand referred to is sea sand, and the grains are rounded. This was obtained from the bed of the Bristol Channel and generally supplied in a wet condition. To put the experiments on a footing somewhat like actual working conditions, the sand was used in a moist state, containing 5 per cent. by weight of water, and in this state it weighed 80 lbs. per cu. ft., filled lightly. When thoroughly dried, its volume became 75 per cent.,

Mixture Number	RATIO BY VOLUME.				A 50% VOIDS.			B 45% VOIDS.			C 40% VOIDS.			D. 30% VOIDS		
	Cement.	Sand.	Stone.		Broken Stone, Uniform Size weighing 80 lbs. per Cubic Foot.			Broken Stone, Variable Sizes, without Dust, weighing 88 lbs. per Cubic Foot.			Gravel, weighing 98 lbs. per Cubic Foot			Graded Stone, weighing 112 lbs. per Cubic Foot.		
					Cement. **Density.** *Strength* (lbs.)	**Sand.** £ *Money Value.* **Absorp. %**	**Stone.** **V. Comp. Vols.** *W. Wear.*	**Cement.** **Density.** *Strength* (lbs.)	**Sand.** £ *Money Value.* **Absorp. %**	**Stone.** **V. Comp. Vols.** *W. Wear.*	**Cement.** **Density.** *Strength* (lbs.)	**Sand.** £ *Money Value.* **Absorp. %**	**Gravel.** **V. Comp. Vols.** *W. Wear.*	**Cement.** **Density.** *Strength* (lbs.)	**Sand.** £ *Money Value.* **Absorp. %**	**Stone.** **V. Comp. Vols.** *W. Wear.*
1	1	—	1	c yds	·80 D 1 60 *571 lbs.*	— *£3 56* 7 70%	80 V ·92 *W 02*	·77 D 1·62 *656 lbs.*	— *£3·49* 9·11%	77 V ·92 *W 00*	·73 D 1·61 *630 lbs*	— *£3·371* 11·07%	73 V ·94 *W 40*	·64 D 1 54 *550 lbs.*	— *£3·77* 10·28%	·64 V ·98 *W ·20*
2	1	—	2	c yds	·56 D 1·68 *367 lbs.*	— *£2·944* 6·40%	1 12 V 95 *W 00*	50 D 1·60 *435 lbs.*	— *£2·72* 8·89%	1·00 V 1·00 *W 03*	·50 D 1·69 *535 lbs*	— *£2·783* 5·83%	99 V 96 *W1 13*	42 D 1·60 *465 lbs.*	— *£2 496* 9·49%	·84 V 1·00 *W 31*
3	1	-	3	c yds	39 D 1 57 —	— *£2·391* —	1·18 — —	37 D 1·58 *335 lbs.*	— *£2·342* 8·95%	1·10 V 1·05 *W ·16*	·36 D 1·67 *340 lbs*	— *£2·377* 7·34%	1·09 V 1·00 *W 35*	·32 D 1·65 *360 lbs.*	— *£2 251* 10·40%	·95 V 1·00 *W 60*
4	1	-	4	c yds	31 D 1 53 —	— *£2 139* —	1 22 — —	29 D 1·54 —	— *£2·09* —	1·14 — —	·27 D 1·58 *195 lbs*	— *£2·062* 7·00%	1·09 — *W ·44*	·25 D 1·66 *255 lbs.*	— *£2 062* 11·04%	1·01 V 1·00 *W 61*
5	1	—	5	c yds	24 D 1·46 —	— *£1·894* —	1·22 — —	·23 D 1·48 —	— *£1·88* —	1·14 — —	·22 D 1·54 *180 lbs.*	— *£1·894* 7·61%	1·10 — *W 16*	·21 D 1·68 *185 lbs.*	— *£1·964* 10·93%	1·05 V 1·01 *W1·07*
6	1	—	6	c yds.	20 D 1 42 —	— *£1·754* —	1 22 — —	·19 D 1·46 —	— *£1·754* —	1 15 — —	·19 D 1·56 *155 lbs*	— *£1·824* 7 33%	1 14 — *W1·60*	·18 D 1·66 *170 lbs.*	— *£1·866* 10·59%	1 06 V 1·02 *W2·02*
7	1	1	1½	c yds	51 D 1 78 *540 lbs.*	51 *£2·874* 6·90%	76 V ·90 *W 00*	·46 D 1·68 *435 lbs.*	·46 *£2·864* 10·09%	·69 V ·96 *W 07*	·42 D 1·61 *385 lbs.*	·42 *£2·503* 7·81%	·64 V 1·00 *W ·08*	·40 D 1·64 *390 lbs.*	40 *£2·468* 9·61%	·60 V 1·00 *W3·10*
8	1	1	2	c yds	43 D 1·72 *530 lbs.*	·43 *£2·608* 7·36%	·86 V ·94 *W 05*	·39 D 1·63 *290 lbs.*	·39 *£2·483* 9·79%	·77 V 1·01 *W ·28*	·37 D 1·64 *325 lbs.*	·37 *£2·384* 7·58%	·75 V 1·00 *W ·53*	·34 D·1·62 *310 lbs.*	34 *£2 286* 10·34%	·67 V 1·03 *W1 33*
9	1	1	3	c yds	33 D 1·66 *350 lbs.*	33 *£2·286* 6·71%	1·00 V 1·00 *W ·07*	·30 D 1·59 *235 lbs.*	·30 *£2·153* 10·09%	·90 V 1·06 *W ·29*	·29 D 1·64 *235 lbs.*	·29 *£2·16* 8·27%	·88 V 1·02 *W ·22*	·27 D 1·66 *255 lbs.*	27 *£2 118* 10·34%	·80 V 1·02 *W1·27*
10	1	1½	2	c yds.	·39 D 1·76 *522 lbs.*	·59 *£2·524* 7 43%	78 V 90 *W 47*	34 D 1·60 *290 lbs.*	·51 *£2·72* 9·80%	·68 V 1·00 *W ·15*	·34 D 1·64 *260 lbs.*	·50 *£2·3* 8·86%	·67 V ·98 *W ·20*	29 D 1·54 *270 lbs.*	·44 *£2·09* 10·61%	58 V 1·05 *W1·58*
11	1	1½	2½	c yds.	34 D 1·70 *330 lbs.*	·51 *£2·342* 6·35%	85 V ·95 *W 20*	·30 D 1·56 *215 lbs.*	·45 *£2·132* 9·79%	·74 V 1·04 *W1·40*	·29 D 1·61 *210 lbs.*	·44 *£2·139* 9·22%	73 V 1·01 *W4·40*	·28 D 1·66 *200 lbs.*	·41 *£2 146* 11·48%	69 V 1 00 *W2 29*
12	1	1½	3	c. yds.	31 D 1·72 *328 lbs*	47 *£2·272* 7·55%	94 V ·95 *W ·10*	·28 D 1·62 *150 lbs.*	·42 *£2·118* 10·27%	84 V 1·01 *W4·17*	·27 D 1·63 *140 lbs.*	40 *£2·097* 9·81%	·80 V 1·01 —	·24 D 1·63 *190 lbs.*	37 *£2·013* 11·75%	73 V 1 03 *W1·97*
13	1	1½	4	c. yds	25 D 1·64 *128 lbs.*	·38 *£2·048* 6·10%	1·01 V 1·02 *W4·68*	23 D 1·56 *120 lbs*	·34 *£1·936* 10·22%	90 V 1·08 *W ·60*	23 D 1·65 *130 lbs.*	34 *£1·999* 10·10%	90 V 1·02 —	·20 D 1·62 *150 lbs.*	30 *£1·894* 11·82%	80 V 1·05 *W2·83*
14	1	1½	4½	c. yds.	·24 D 1·68 *125 lbs.*	·36 *£2·048* 6·59%	1·08 V 1·00 *W 5·80*	21 D 1·54 *90 lbs.*	·31 *£1 866* 9·49%	·93 V 1·10 *W4·40*	·21 D 1·67 *95 lbs.*	·32 *£1·957* 9·63%	·95 V 1·02 —	·19 D 1·65 *130 lbs.*	·28 *£1·887* 10·62%	·84 V 1·04 *W5·05*
15	1	1½	5	c. yds.	·23 D 1·70 *158 lbs.*	·34 *£2·034* 5·98%	1·13 V 1·00 *W1·30*	·19 D 1·54 *95 lbs.*	29 *£1·81* 9·65%	·96 V 1·13 *W2·77*	·20 D 1·67 *100 lbs.*	·29 *£1·929* 9·46%	·98 V 1·02 *W11·94*	·18 D 1·70 *135 lbs.*	·27 *£1·894* 11·43%	·89 V 1·01 —
16	1	2	3	c. yds.	·28 D 1·68 *235 lbs.*	·56 *£2·16* 7·83%	·84 V ·95 *W ·30*	26 D 1·62 *115 lbs.*	·51 *£2·062* 11·23%	·77 V1·00 *W2·43*	·25 D 1·63 *110 lbs.*	·49 *£2·041* 10·26%	·74 V 1·00 —	22 D 1·61 *160 lbs.*	·45 *£1·943* 10·70%	·67 V 1·02 *W1·05*
17	1	2	4	c. yds	·24 D 1·67 *150 lbs.*	·48 *£2·041* 6·44%	·95 V ·99 *W ·30*	·21 D 1·53 *105 lbs.*	·42 *£1·659* 9·37%	·82 V 1·09 *W2·65*	·21 D 1·64 *95 lbs.*	·42 *£1·936* 9·72%	·84 V 1·00 —	10 D 1·62 *110 lbs.*	·28 *£1·866* 12·50%	·75 V 1·04 *W5 16*

CONCRETE MIXTURES AND COMPARATIVE RESULTS.

Mixture Number.	RATIO BY VOLUME. Cement.	Sand.	Stone.		A. 50% VOIDS.			B. 45% VOIDS			C. 40% VOIDS.			D 30% VOIDS.		
					Broken Stone, Uniform Size, weighing 80 lbs. per Cubic Foot.			Broken Stone, Variable Sizes, without Dust, weighing 86 lbs. per Cubic Foot.			Gravel, weighing 96 lbs per Cubic Foot.			Graded Stone, weighing 112 lbs. per Cubic Foot.		
					Cement. Density. *Strength (lbs.)*	Sand. *£ Money Value.* Absorp. g.	Stone. V. Comp. Vols. *W. Wear*	Cement. Density. *Strength (lbs.)*	Sand. *£ Money Value.* Absorp. g.	Stone V. Comp. Vols. *W. Wear*	Cement. Density. *Strength (lbs.)*	Sand. *£ Money Value.* Absorp. g.	Gravel. V. Comp. Vols. *W. Wear.*	Cement. Density. *Strength (lbs.)*	Sand. *£ Money Value.* Absorp. g.	Stone. V. Comp. Vols. *W. Wear.*
18	1	2	5	c yds	·20 D 1·63 *100 lbs.*	·41 *£1·901* 6·59g	1·02 V 1·02 *W3·01*	·17 D 1·46 *50 lbs.*	34 *£1 698* 17 35g	·86 V 1 14 *W9 30*	18 D 1 65 *30 lbs*	37 *£1 859* 5 05g	92 V 1 01 —	17 D 1 66 *120 lbs*	33 *£1·838* 11 77g	·83 V 1 02 *W3 56*
19	1	2	6	c yds	16 D 1 45	32 *£1 663*	97 V 1 15	16 D 1·55	32 *£1 733*	1 97 V 1 09	17 D 1 71	·34 *£1 873*	1 00 V 1 05	15 D 1 71	30 *£1 817*	90 V 1 01
20	1	2½	3	c yds	27 D 1 76 *250 lbs.*	68 *£2 168* 6·89g	81 V ·90 *W1 35*	·23 D 1·58 *180 lbs*	58 *£1 95* 8·91g	70 V 1·01 *W3·07*	23 D 1 62 *150 lbs.*	57 *£1 978* 14 30g	·68 V 1·00 *W3 68*	·21 D 1·61 *100 lbs*	52 *£1 917* 15 12g	63 V 1 00 *W3 80*
21	1	2½	4	c yds	22 D 1 63 *255 lbs*	54 *£1 957* 6·69g	·87 V 1·00 *W1 70*	21 D 1·62 *110 lbs.*	51 *£1·[illegible]* 11 87g	82 V 1 00 *W4 68*	20 D 1 64 *115 lbs*	49 *£1·908* 9·20g	79 V 1 00 *W 97*	18 D 1 66 *80 lbs*	46 *£1 866* 12 68g	73 V 1 00 *W5 73*
22	1	2½	5	c yds	20 D 1·69 *180 lbs*	50 *£1·943* 7·14g	99 V ·98 *W2·37*	18 D 1 62 *120 lbs.*	·45 *£1·838* 10 57g	90 V 1 02 *W4 96*	17 D 1 66 –	44 *£1·831* 10·13g	87 V 1 00 ·	16 D 1 67 *70 lbs*	40 *£1 817* 11·67g	·79 V 1 01 *W3·55*
23	1	2½	6	c yds	18 D 1 67	44 *£1 873*	1·05 V 1·00	16 D 1 61	40 *£1 775*	95 V 1 05	16 D 1 68	39 *£1 824*	94 V 1 00	14 D 1 67	35 *£1 761*	84 V 1 01
24	1	2½	7	c yds	15 D 1 60	38 *£1 740*	1·07 V 1 05	·14 D 1·54	34 *£1 67*	96 V 1 10	14 D 1 63	34 *£1 733*	96 V 1 04	13 D 1 70	32 *£1 774*	89 V 1 01
25	1	3	4	c yds	20 D 1 60 *260 lbs*	60 *£1 88* 7 29g	·80 V 00 *W 64*	19 D 1·60 *115 lbs*	57 *£1 852* 10 28g	76 V 1 01 *W1·25*	19 D 1 64 *30 lbs*	56 *£1 84* 9 79g	74 V 1 00 *W4 30*	17 D 1 63 *80 lbs.*	51 *£1 817* 12 27g	·66 V 1 00 *W5 15*
26	1	3	5	c yds	18 D 1 62 *175 lbs*	54 *£1·838* 6 69g	90 V 1·00 *W1·66*	17 D 1 62 *55 lbs*	51 *£1 81* 11 43g	85 V 1·01 *W11·75*	16 D 1 63 *110 lbs*	49 *£1 789* 8 67g	82 V 1 00 *W10·35*	15 D 1 66 *30 lbs.*	45 *£1·762* 14 68g	76 V 1 00 —
27	1	3	6	c yds	17 D 1 65 *120 lbs.*	49 *£1 831* 7·26g	99 V 1·00 *W3 53*	15 D 1·55 *60 lbs.*	44 *£1 705* 11·02g	87 V 1·08 *W8 35*	15 D 1·67 *95 lbs*	45 *£1 789* 9 34g	89 V 1 01 *W6 25*	14 D 1·70 *40 lbs*	41 *£1 782* 12 53g	82 V 1 00 *W12·90*
28	1	3	7	c yds	14 D 1 57 *145 lbs*	43 *£1·691* 7 15g	1·00 V 1·06 *W 77*	13 D 1·51 *65 lbs*	39 *£1 621* 9 84g	90 V 1 11 —	13 D 1 65 *110 lbs*	39 *£1 719* 9,80g	94 11 01 —	12 D 1·69 *30 lbs.*	3 *£1 719* 10 98g	86 V 1 00
29	1	3	8	c yds	13 D 1·51	38 *£1 621*	1 00 V 1 11	12 D 1 48	·35 *£1·572*	92 V 1 14	·12 D 1·64	36 *£1·681*	97 V 1 03	11 D 1 71	34 *£1 705*	90 V 1 00
30	1	4	5	c yds	·16 D 1·60 *100 lbs.*	64 *£1 768* 8·36g	80 V 1·00 *W1·97*	15 D 1·53 *80 lbs.*	58 *£1·691* 10·49g	73 V 1·04 *W7 69*	15 D 1 62 *90 lbs.*	59 *£1·754* 10·31g	73 V 1·00 *W13·15*	14 D 1 64 *30 lbs.*	55 *£1 74* 15 11g	68 V 1 00 *W16·55*
31	1	4	6	c yds	15 D 1 62	59 *£1 754*	·88 V 1·00	·13 D 1·51	·52 *£1·621*	78 V 1 08	13 D 1 64	54 *£1·712*	81 V 1 00	12 D 1 63	49 *£1 677*	73 V 1 01
32	1	4	7	c yds	·14 D 1·63	54 *£1 733*	·95 V 1·00	12 D 1 55	·49 *£1·621*	·85 V 1·08	·12 D 1 64	·49 *£1·664*	86 V 1 00	11 D 1·65	45 *£1 663*	78 V 1 01
33	1	4	8	c yds	·18 D 1 66	51 *£1 726*	1·02 V 1·00	11 D 1·49	43 *£1·551*	·86 V 1·12	·11 D 1·64	·45 *£1·656*	·90 V 1·01	·10 D 1·66	41 *£1 642*	82 V 1 01
34	1	4	9	c. yds	·12 D 1·65	·47 *£1·691*	1·06 V 1·01	10 D 1·48	·40 *£1·516*	89 V 1 11	10 D 1·63	·41 *£ ·621*	·93 V 1·03	10 D 1·68	38 *£1 656*	86 V 1·01
35	1	4	10	c yds	11 D 1·65	·44 *£1·663*	1·10 V 1·01	·09 D 1·45	·36 *£1·4 7*	91 V 1 15	·09 D 1·60	·38 *£1 572*	94 V 1·05	·09 D 1·68	34 *£1·626*	89 V 1·01
36	1	5	10	c yds	·10 D 1·63	·51 *£1·681*	1·02 V 1·02	·08 D 1·41	·42 *£1·411*	·83 V 1·18	·09 D 1·53	42 *£1·523*	·85 V 1 09	·08 D 1·66	·42 *£1·60*	·84 V 1·00

CONCRETE MIXTURES AND COMPARATIVE RESULTS.

or 101 lbs. per cubic ft., the weight of water being lost in the process of drying.

It is generally considered that wet sand is heavier than dry sand, and although this is correct for sand undisturbed, and with water poured into it, the rule does not apply to sand thrown about as is the case when the mixing of concrete occurs. This fact is very important in dealing with concrete mixtures, a ratio of 1—3—6 measured by volume using moist sand containing 5 per cent. of water being the same as 1—4—6, when using dry sand.

When using sand containing 5 per cent. moisture, as was the case during the experiments, it was found that the voids (containing air and water) were practically 50 per cent.

The weight of the sand used was therefore the same as the cement, as also was the weight of aggregate " A."

The grains of the sand used also varied in size, the analysis being as follows :—

	Per cent.
Over 0·05 in.	7
0·05 in. to 0·03 in. . .	13
0·033 in. and under . .	80

This variation in the sizes of the grains reflects itself in compactness and also in strength. In the course of experiments in 1922 it was found that briquettes gave the following comparative tensile results after 28 days for 1 to 3 mixtures :

	lbs.
Sand of the above analysis	294
Ditto not more than 0·05 in. and not less than 0·03 in.	168
Crushed limestone do. do. do.	258

This limestone is the same kind as the stone used for the 1923 experiments, and the angular grains prove to be much stronger than rounded grains. This repeats itself in the use of a sea gravel, and the following results are also for 1 to 3 mixtures of the same period :

	lbs.
Channel gravel . . .	436
2 parts ¼ in. limestone, 1 part sand.	509

The result of the neat cement briquettes of the same period was 710 lbs.

An increase in the sizes of the rounded grains also finds a corresponding increase in the results of the tensile tests, the sand result being 294 lbs. and the Channel gravel 436 lbs.

The same also applies to the angular grains, for the sand size grains give a result of 258 lbs. as compared with 509 lbs. for ¼-in. stone, which was supplemented in this case with an addition of sand.

The aggregates other than sand are in four classes lettered A, B, C and D. The stone used in A, B and D is the same quality but in various forms. This stone is a dolomite limestone of a reddish colour high in silica, and can be classified as an average type of crushed stone aggregate, being neither very hard nor very soft ; its weight per cubic foot of solid stone when thoroughly dry was very near 160 lbs. per cu. ft.

For the experiments, a size of aggregate not greater than ⅜ in. was adopted, as it was desired to test the concrete in briquette form.

From the standpoint of economics, the cost of the aggregate, when bought by weight, depends first upon the specific gravity of the stone or the weight per volume of solid stone. Another important factor is the percentage of voids. For instance, for a heavy granite weighing 190 lbs. per cu. ft. of solid stone with extremes of 20 per cent. and 50 per cent. voids, the weights are respectively 1·832 tons and 1·145 tons per cu. yd., while a difference of 5 per cent. of voids amounts to ·086 tons. Experiments with the same stone, but of different sizes, indicate that stones of uniform sizes, however large or small, have practically the same percentage of voids, namely about 50 per cent. when lightly filled into a measure.

Aggregate A.—This is clean crushed stone of a uniform size of ⅜ in., weighing 80 lbs. per cu. ft., the percentage of voids being 50 per cent. when lightly filled. For actual practice of measuring the ratios in large heaps, 45 per cent. would probably be a nearer percentage of voids, owing to its own weight assisting in compacting it.

Aggregate B.—This is ⅜-in. crusher run, with the dust removed. It passes through a ⅜-in. sieve, and is retained on the 0·05 sieve. It weighs 88 lbs. per cu. ft., the percentage of voids being 45 per cent. when lightly filled, but does not compact as much as Aggregate A when shaken. The analysis by weight is as follows :—

	Per cent.
⅜ in. to ¼ in.	28·3
¼ in. to ⅛ in.	24·4
⅛ in. to ·05 in. . . .	47·3

Aggregate C.—This is an entirely different aggregate from the others, it being a sea gravel of rounded grains. Experiments revealed that the solid contents of the grains could be put on the same basis as the limestone used, namely, 160 lbs. per cu. ft. When containing 5 per cent. by weight of moisture it weighed 96 lbs. per cu. ft. when lightly filled, the percentage of voids being 40 per cent., and it was used in this state.

When dried it did not shrink as much as the sand, but it became 0·85 of its bulk when moist, and its weight per cu. ft. when dry would be correspondingly more. It is, however, sold in a wet state, and in compiling these results, the lecturer bore in mind that he personally requires their use in the economic performance of his everyday duties. The analysis by weight is as follows :—

	Per cent.
⅜ in. to ¼ in.	11·5
¼ in. to ⅛ in.	27·4
⅛ in. to ·05 in. . . .	38·7
·05 in. to ·033 in. . .	12·0
·033 in. and under . .	10·4

Aggregate D.—The stone used for this aggregate is the same as that of Aggregates A and B, but the percentage of voids has been reduced to 30 per cent. and the weight of the aggregate becomes 112 lbs.

The ratios were taken on the volume basis, but with the knowledge of previous experience, the quantities were carefully weighed in order more accurately to ensure the correct ratio. With the knowledge of the relationship between the volumes of the aggregates and their weights, this was fairly simple, though involving some calculation.

No attempt was made scientifically to gauge the water contents of the mixtures. The mixtures were, however, carefully mixed, and in each case brought to the consistency of a mortar not sloppy with excess of water, and yet not without sufficient moisture to enable it to hang together.

After mixing the resultant volumes were measured, and mixtures sufficiently fat for the purpose were made into briquettes of the usual size, two briquettes being made of each mix. After 24 hours they were released from the moulds and immersed in water for six days, and then left to dry for another 21 days before testing them for tensile strength.

In the A mixtures, the figures for volumes are also comparative for weights, as the three constituents are on the same basis, namely, 80 lbs. per cu. ft., the voids being 50 per cent. These quantities are the results of practical experiments, and all executed under the same conditions.

Comparing the results of the first six mixtures in which sand has not been used, it will be observed with the A aggregate that however much the quantity of cement is lessened the aggregate does not decrease beyond 1·22 cu. yds. For mixtures richer than 1 to 4, the cement not only aids in filling the voids but also increases the bulk of the concrete, for the quantities of aggregate become less than 1·22 cu. yds. Aggregate B shows less compacting, the quantity of aggregate in the 1 to 6 mixture being 1·15, while for C it is 1·14 cubic yards and for D 1·06 cu. yds. Mixtures of such a ratio using aggregates A and B are not of much practical use, but the lecturer experimented on them in order to find this particular point.

The ratios are by volume, and the weights of the four aggregates vary. When comparisons by weight are made it will be seen that the " A " mixtures contain more cement than the other mixtures. This is of considerable importance when other comparisons of results are made. For instance, on the basis of weight comparisons, the A 6 mixture (1 to 6) would be on a par with the C 5 mixture (1 to 5), as the A aggregate is 20 per cent. lighter than the C aggregate.

DENSITY.

Perhaps the most interesting series of results is that dealing with the comparative densities and preceded by a " D " in the table.

These are found from the results of the quantities of the various materials in the mixtures, and are arrived at as follows :—

Taking Mixture No. 7 as an example and commencing with the A mixture, we have cement 0·51 cu. yds., sand 0·51 cu. yds., and stone 0·76 cu. yds. For the A mixture these materials are all of the same basic weight, namely, 80 lbs. per cu. ft., each with 50 per cent. of voids. So they are added together, the total of 1·78 being recorded as the density figure.

When we come to the B mixture, the circumstances vary, for here we have a stone 10 per cent. heavier than A, owing to a less percentage of voids. Using the same ratio, we add again, but on this occasion adding the 10 per cent. increase.

Cement	·46 cu. yds.
Sand	·46 „
Stone	·69 „
Add 10%	·069 „
	1·679

Using fractions to two decimal places only, this becomes 1·68.

The densities of mixtures C and D are found by means of the same method. It will be seen that there is more than one purpose in adopting this method of showing the comparisons.

In the first place the relationship between the quantities of materials and the quantity of concrete is direct for volumes of the A mixtures. Taking mixture No. A 7, again it will be seen that it takes 1·78 cu. yds. of materials to make 1 cu. yd. of consolidated concrete. As the results of this column range from 1·42 to 1·78 it is obvious that the old rule of contraction being 25 per cent. is not altogether a safe one.

In dealing with the density figures in this way and ignoring water contents, we also maintain a comparison of the weights of the respective concretes, whatever their classes of aggregate may be.

When the four classes of mixtures are compared it will be seen that the effort of obtaining a denser aggregate is not reflected to any appreciable extent in obtaining denser concretes.

The following is a comparison of the averages for the 36 ratios :—

A.	B.	C.	D.	Mean.
1·63	1·55	1·63	1·65	1·62

It will be seen from these averages that A and C are alike while B, although with a denser aggregate than A, is actually less dense in concrete, while D, although with a very dense aggregate, is very little denser in concrete than A, and the mean of 1·62.

Not only in concrete, but in the mixing of aggregates it was found that to add ¾-in. stone to 2¼-in. stone (both of uniform sizes) meant an increase in the bulk of the mixed aggregate to the extent of the volume of the added stone, though it was of smaller size. Even in mixing ¼-in. stone with 2¼-in. stone in equal parts, the resultant volume became only 13 per cent. less than the total of the separate volumes. Some of the smaller aggregate tucks itself away in the interstices of the larger aggregate, but also works itself between the larger stones and keeps them apart, thereby decreasing the percentage of voids in one way and increasing it in another.

If, however, the percentage of voids is not materially decreased in the concretes as these experiments tend to show, the sizes of the voids are materially lessened. The area of aggregate grains is also less by grading, and this has also an important bearing upon the strength of the concrete.

The percentage of voids in cement is taken as 50. In order, therefore, to find the percentage of voids in concrete mixtures (ignoring the pores in the aggregate) we have the following simple formula :—

Halve the density figures, subtract the result from 1·0 and multiply by 100. Taking the result of 1·68 dealt with previously, a percentage of 16 per cent. is determined as follows :—

$$\left[1 - \frac{1{\cdot}68}{2}\right] \times 100 = 16\% \text{ voids.}$$

MONEY VALUES.

On the basis of weights the cement is taken as costing five times as much as the aggregate, and although this would vary according to the locality such a ratio has been taken as a proportion of general service.

The cement is taken as 72*s*. 7*d*. per ton, which is equivalent to 70*s*. per cu. yd., and includes bag hire, returns and incidentals. The sand is taken as 14*s*. 6¼*d*. per ton or 14*s*. per cu. yd. Aggregate A is on the same basis as the sand. Aggregate B is at 14*s*. 6¼*d*. per ton, and 15*s*. 4¾*d*. per cubic yd. Aggregate C 14*s*. 6¼*d*. per ton and 16*s*. 9¾*d*. per cu. yd., and Aggregate D 14*s*. 6¼*d*. per ton and 19*s*. 7¼*d*. per cu. yd. From an economic point of view, these prices of aggregates, although identical in the prices per ton, show a variation in the prices per cu. yd. If they were taken on a flat rate per cu. yd. the price per ton would vary, so that in purchasing aggregate there is a good deal to consider, and in either case it would pay to buy the aggregate in a dry state.

The comparative money values for the various mixtures speak largely for themselves, and are compiled for the sake of reference and comparison with the other data.

The average costs per cu. yd. are as follows :—

A.	B.	C.	D.
£2·055	£1·933	£1·976	£1·950

In finding the money values, labour at 4*s*. per cu. yd. has been allowed for mixing the concrete ready for use.

COMPARATIVE VOLUMES.

In order to compare the results of the respective volumes of cement and aggregate in these experiments, their relative comparisons with the quantities given by Messrs. Taylor and Thompson are shown in the table, and on the basis of the writer's own experiments being 1·00, these are shown in decimal fractions. These figures can easily be converted into percentages by multiplying by 100. Taking mixture A 7 as an example, it will be seen that Taylor and Thompson's ratio volumes are 0·90 × 100 = 90 per cent., or 10 per cent. less than that of the author.

The averages of these comparative volumes are as follows :—

A.	B.	C.	D.
0·993	1·059	1·009	1·012

Experiments in 1922 indicated that although using the stone of the same quarry and the same sieves there was a difference in the compacting of the stone of three different size crushers, which could only be attributed to the varying shape of their products.

The following figures show the results of using Aggregate A in a 1—1½—3 mixture (A 17) the result of the ⅜-in. stone being considered as 1·00 :—

¼ in.	⅜ in.	½ in.	¾ in.	1 in.	1½ in.	2 in.
1·05	1·00	·86	·93	·93	·93	·93

It will be seen from this that the use of ½-in. stone is the most expensive and the ¼-in. stone the cheapest.

STRENGTH.

The strength of the briquettes was tried at the end of a period of 28 days. After being allowed to set for one day, they were put in water for six days, then taken out and left for 21 days before testing. Two briquettes were made to each mixture and the results recorded are the best in each case. The result of the neat cement briquette was 765 lbs. Briquettes were not made of the very poor mixtures.

The results show a great variation, and when compared give considerable food for thought, whilst when further compared with the figures of relative densities and money values they become very complex.

The averages are as follows :—

A.	B.	C.	D.
269·045	384·608	350·600	311·731

The graded mixture is not the success it was expected to be, though better results would probably have been achieved with the use of granite in lieu of limestone. The best results are from the B mixtures, though the more surprising one is that of C, which has an aggregate of rounded grains.

ABSORPTION.

After drying the briquettes thoroughly they were half immersed in water for 7 days, being weighed before and after, and the difference shown on the table in grammes. The averages of the increases in weights brought about by absorption consequent upon this process, are as follows :—

A.	B.	C.	D.
6·970	10·366	8·980	11·364 grammes.

WEAR.

The same briquettes were again tested for wear many months after the previous experiments in the following way :—

The end of a briquette of each mixture was clamped in a shaping machine and comparable areas given 12 strokes with a worn rasp in one minute ; the rasp was travelling 3 in., weighed with 31 lb., and had a wearing action on both forward and return strokes. The briquettes were weighed before and after this wear test, and the results given in the table and preceded by the letter W indicate the loss in grammes. Some of the mixtures did not stand the strain of clamping, and where this occurred, a dash indicates the failure to get a result. It will be observed that no impression was made on some mixtures, the results being shown as W0·00.

The general comparison between the four aggregates (averages) are as follows :—

	A.	B.	C.	D.
Wear, loss of weight in grammes.	1·377	3·107	3·575	3·561

The average loss for two neat cement briquettes is 0·025 grammes, and the best wearing results were obtained from the A mixtures.

THE INSTITUTION OF STRUCTURAL ENGINEERS.

ELECTION OF OFFICERS AND COUNCIL.

A SPECIAL General Meeting of the Institution of Structural Engineers was held on May 22, when the result of the ballot for the election of Officers and Council for the Session 1924–5 was announced as follows:—

President (One year)—James Petrie.
Vice-Presidents (One year)—H. J. Deane, J. S. Owens, Sir Charles Ruthen, H. K. G. Bamber.
Honorary Secretary (One year)—H. Kempton Dyson.
Honorary Editor (One year)—Ewart S. Andrews.
Honorary Librarian (One year)—W. J. H. Leverton.
Honorary Curator (One year)—S. Bylander.
London Members of Council (Three years)—W. A. Green, R. H. H. Stanger, Oscar Faber.
Country Member of Council (Three years)—G. B. R. Pimm.

THE COST OF CONCRETE ROADS.

SPEAKING at a recent meeting of the Institution of Municipal and County Engineers, Mr. Frank Hewitt, F.S.I., Engineer and Surveyor to the Kiveton Park Rural District Council, gave some figures as to the cost of concrete roads recently built in his area. A road diversion on a clay subsoil was, he said, over a year ago carried out by direct labour successfully in reinforced concrete without the aid of machinery at the following cost, exclusive of excavation, drainage, kerbing, etc., but inclusive of protection, curing, use of plant, water for soaking underbed, mixing, etc. :—

	s.	*d.*
Materials and carting for concrete	6	4¾
Reinforcement, including carting and fixing	2	1¼
Labour	1	11¼
Total (per sq. yd.)	10	5¼

The road bed was first underdrained and covered with a layer of boiler clinker and rolled. The lower 4 in. of concrete was composed of 4 parts local limestone (1½ in.), 2 parts Worksop sand, and 1 part slow-setting cement to British Standard Specification. The steel reinforcement was embedded at a uniform distance of 1½ in. from the underface of the concrete bed. The upper 2-in. or wearing layer of concrete consisted of 3½ parts Penmaenmawr ⅜-in. granite screenings containing 20 per cent. of granite dust to 1 part of Portland cement. The minimum quantity of water was used and strict supervision exercised throughout to ensure cleanliness, proper mixing and laying. Tarpaulins and bags were used for protecting the concrete from the sun, rain, frost and drying winds, and a layer of frequently-moistened sand for preventing too rapid drying of the concrete. The road surface is very clean, gives good foothold for horses, ease of traction and excellent visibility at night.

In the Council's depôt alongside the railway siding about 40 lin. yards of concrete road 5 in. thick (not reinforced) had been put down at a cost of 7*s.* 3*d.* per sq. yd. In this case the top layer was composed of 1 part cement, 1 Worksop sand, 3 slag screenings.

UNSURFACED CONCRETE ROAD AT YARMOUTH.

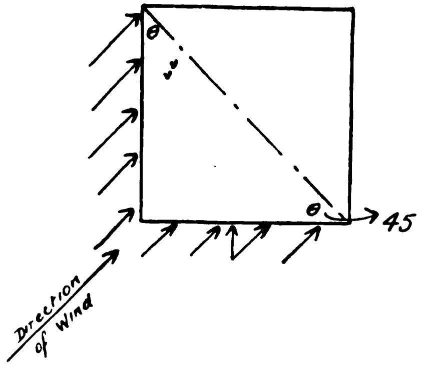
The above photograph shows the Marine Parade, South Extension, Great Yarmouth, which is now in course of construction as an all-concrete road. The concrete is 6 in. thick, reinforced with B.R.C. Fabric, and laid in two courses; a lower course 4½ in. thick and a top course 1½ in. thick, laid in alternate bays.

QUESTIONS AND ANSWERS RELATING TO REINFORCED CONCRETE.

Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—Ed.

WIND PRESSURES.

Question.—I would be obliged if you would give me your views with regard to the following basis for calculating wind pressures on structures. Taking the case of the reinforced concrete water tower in your issue for February, Dr. Faber gives the effective wind pressure as acting on one side of the tank only. Would it not be proper to consider the wind acting on a corner as shown in the diagram and the pressure worked out on Duchemin's formula ? :—



$$pn = p\frac{2 \sin \theta}{1 + \sin^2 \theta}$$

This would give

$$pn = 30 \cdot \frac{2 \times \cdot 707}{1 + (\cdot 707)^2}$$

$$= 30 \cdot \frac{1 \cdot 414}{1 \cdot 5}$$

$$= 28 \cdot 28 \text{ lbs. per sq. ft.}$$

and then taking the area of two sides

$$2 \times 18 \times 10 = 360 \text{ sq. ft.}$$

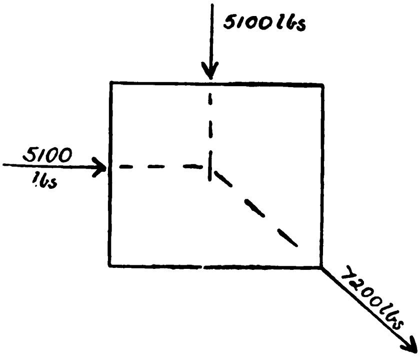
the pressure would then become

$$360 \times 28 \cdot 28 \text{ lbs.}$$

$$= 10{,}180 \text{ lbs.}$$

I have only worked this out for the tank itself, and since it would also affect the pillars and braces in the same manner it shows a considerable increase and one which I think ought to be taken into account.—J. R. R.

Answer.—There is no objection to using Duchemin's formula for wind pressure, but it gives a result somewhat different from that arrived at by our correspondent. The normal pressure is, as he says, 28·28 lbs. per sq. ft., whence the pressure on one side is 18 ft. × 10 ft. × 28·28 lbs. per sq. ft. = 5,100 lbs.



Resolving these two forces of 5,100 lbs., (see sketch) the resultant is

$$P = 1 \cdot 414 \times 5{,}100 = 7{,}200 \text{ lbs. approximately,}$$

instead of 10,180 lbs.—O. F.

FINE GRINDING OF CEMENT.

A REPORT has been issued by the Research Laboratory of the Blast Furnace Cement Industry at Dusseldorf dealing with the results of an elaborate series of experiments on the effect of a greatly-increased fineness of grinding on both tension and compression tests. The investigation was apparently intended to see whether the best results could be obtained by alternative methods of grinding :—

(1) The genuine cement clinker fine, and the added slag coarse, before intermixture ; or by
(2) Reversing this plan, and grinding the cement clinker coarse, and the slag fine ; or by
(3) Grinding each separately before admixture ; or by
(4) Grinding them together.

Incidentally, they hoped to find out whether by extremely fine grinding they could reduce the proportion of genuine cement clinker necessary to excite the relatively inert slag into chemical activity.

It may be remembered that the Passow theory concerning slag was that whereas it remained inert, even after grinding, when mixed with plain water, the substitution of an alkaline solution for pure water acted like the composition on the box acts on a safety match, and aroused its dormant chemical qualities into activity. Finding in a solution of ordinary Portland cement the alkaline solution needed for this purpose, he advocated the mixture of genuine Portland cement and slag, which resulted in a compound of stable character when dry but which after the addition of water (and the solution of the Portland cement in the mixture which results in the creation of the alkaline solution required) would thereby become chemically active throughout and serve all the purposes of a pure Portland cement. Upon this theory, which has largely justified itself in practice, the whole structure of the Eisen Portland cement industry has been built up. This report briefly reiterates the above as the function of the genuine Portland cement clinker in the mixture, and then adumbrates the possibility that an extremely fine grinding of the Portland cement would enable it to act more powerfully upon the inert slag and so reduce the percentage of Portland cement in the final mixture.

It is unnecessary to translate in detail the respective results of this very complicated series of tests, but something may perhaps be learned by examining the figures for tensile and compressive strengths obtained from varying degrees of fineness. A sample of blast furnace slag cement was taken and then ground in the laboratory mill for varying periods of 3, 6, 9 and 18 hours respectively, after which the resulting powders were tested at 3, 7, and 28 days and at 6 months. The residues on the usual 900 mesh and 5,000 mesh sieves are given in each case, and also that on one of 10,000 meshes per square centimetre, i.e. about 65,000 per sq. in., but the report points out that this method is insufficient to show the real degree of fineness attained. As the German testing methods comprise storage in air as well as in water, and what they call "combined storage" for some of the tests, and as these convey little to our minds, we have extracted the figures for storage in the ordinary way, i.e. 24 hours in air and the rest of the time in water. This simplifies the table, and gives what is most material.

It is admitted that the extra cost of the fine grinding would prove greater than the increase in strength warrants, but the results are nevertheless worth noting.

FINENESS

	Residues on sieves per sq. cm.		
	900.	5,000.	10,000.
As received	0·1	3	10
After 3 hours' grinding .	0·1	1·4	5·2
,, 6 ,, ,, .	0	1	2·6
,, 9 ,, ,, .	0	0·6	2·6
,, 18 ,, ,, .	0	0·9	2

SETTING TIME

	Initial.	*Final.*
As received	½ hrs.	7 hrs.
After 3 hours' grinding . .	2	5½
,, 6 ,, ,, . .	1	3½
,, 9 ,, ,, . .	½	3
,, 18 ,, ,, . .	¼	1

TENSILE STRENGTH

	3 days. Kg.	7 days. Kg.	28 days. Kg.	6 mos. Kg.
As received	9·7	16·7	24·3	28·7
After 3 hrs.	11·3	19·4	25·7	31·3
,, 6 ,,	18	20·8	25·7	31·2
,, 9 ,,	16·2	19·8	26·3	30·2
,, 18 ,,	25·5	24·7	28·5	35·8

COMPRESSION STRENGTH

	3 days.	7 days.	28 days.	6 mos.
As received	101	179	255	417
After 3 hrs.	156	217	328	449
,, 6 ,,	167	251	339	483
,, 9 ,,	173	235	341	447
,, 18 ,,	237	308	357	449

The above were all with the usual proportion of 1 to 3. Those below were obtained from a mixture of 1 cement to 7 sand :—

TENSION

3 days.	7 days.	28 days.	6 mos.
5	7	10	12·6
5·7	8·4	10	12·3
7	8·9	11	12·5
9	9·5	13·3	15
9	8·4	12·5	10

COMPRESSION

3 days.	7 days.	28 days.	6 mos.
34	52	84	84
51	62	73	98·6
40	70	87	95
51	70	91	100
64	80	92	112

CENTRIFUGAL CONCRETE MIXER.

WE learn that a new type of concrete mixer, embodying the centrifugal principle, has been designed and experimented on by Mr. N. C. Johnson, of Messrs. Hool & Johnson, the well-known firm of New York consulting engineers.

In shape and appearance this machine resembles the usual type of revolving-drum mixer mounted with a power unit on a stationary truck. The drum of the mixer revolves at 80 r.p.m. It has an internal diameter of 40 in. and a width at centre of 18 in. The output is 11 cu. ft. of mixed concrete per batch. Compared with a typical bath-type mixer of the same capacity this machine is thus smaller in bulk and revolves at a speed four or five times as great.

The use of a small drum for a comparatively large output of mixed concrete is made possible by the centrifugal principle which utilises more than 90 per cent. of the drum volume for holding the materials to be mixed, as against the utilisation of about 25 per cent. of the drum volume in the case of a drum which rotates at the low speeds commonly employed. The drum is not equipped with the multiple mixing blades used on most other mixers, but the aggregates are forced out toward the periphery of the drum by centrifugal action and are diverted along a pre-determined path at the zenith of their travel. The drive may be by a petrol engine mounted on the truck or by belt. The drum is supported by trunnion wheels between cast frames.

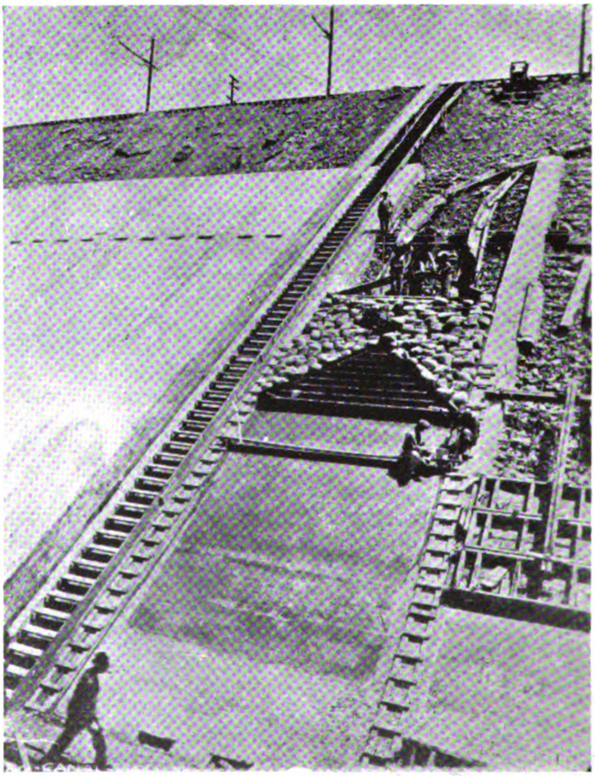
Among the advantages claimed for the centrifugal mixer are small size combined with large output, portability, thorough and rapid mixing, and a proper consistency of the mixed batch, almost regardless of the amount of water used, within permissible limits.

The scouring action during the mixing process is said to result in a good concrete, even with dirty aggregate. This last feature, it is pointed out, makes possible a better average concrete, due to more intimate contact of cement with the surfaces of the aggregates, and a ballast coated with clay, which usually results in an absorbent, spongy concrete may be used with good results. The centrifugal machine is stated to utilise economically even fine sands which are commonly assumed to be unfit for use. Further, any agglomerated lumps are broken down in mixing, so that the mass throughout is an even and intimate union of minerals.

SLIDING STEEL FORMS IN CANAL CONSTRUCTION.

In lining parts of the Queenstown-Chippawa power canal at Niagara Falls an interesting sliding steel form was used. The sliding form was made of one thickness of ¼-in. steel plate with 9-in. channels around the outside and reinforced with 9-in. channels placed horizontally across the plate at 9-in. centres.

In size the forms measured 16 ft. by 17 ft. The drawbar was a continuation of the side channels brought together so as to protrude about 6 ft. ahead of the form. At the top of the slope being concreted was a hand-winch pulling the form upwards by a steel cable attached to the form. The first 20 ft. of the slope was concreted by usual methods in order to get a start for the sliding form. After this lower section had set the steel form was placed upon it, and pouring in front of the form was continued as it was moved slowly up the slope. It is claimed that by the time the plate had passed over the concrete it was sufficiently set to stay in place, and when the weather was warm and the concrete fairly dry a distance of 55 ft. up the slope was accomplished in ten hours.



Sliding Steel Forms used in Canal Lining.

CONCRETE PRODUCTS

CONCRETE ON THE FARM.

We give below the essay placed first, and awarded a premium of £20, in the Students' Section of the recent essay competition organised by the Concrete Utilities Bureau. The essay is by Mr. David T. Adam, of Ladenford, Forfar, and contains many hints which should be useful to those interested in farm and estate work :—

Concrete is composed of a mixture of cement, sand, aggregate and water, although strictly speaking the term aggregate includes sand. The proportion of each constituent present depends on the ultimate use of the concrete. The aggregate is composed of such materials as gravel, stone, broken brick, granite chips, clinker, or coke breeze. Of these, probably gravel and stone are most common, as they are home products, and the only expense is in the labour of procuring them. Sand is also obtained locally ; but there are certain points to notice when choosing the aggregate and sand.

The aggregate should be hard, free from dust, preferably impervious to moisture, and of convenient size. The sand should be clean, graded, coarse in texture, pure, and preferably sharp. There should be no clay or silt present, for they act as a protective layer and prevent proper adhesion between the cement and other constituents. The aggregate and sand should be graded from the largest size chosen to the finest sand, and in this way a compact mass is obtained on mixing, the cement merely acting as a binding material, by reason of the fact that when wetted and allowed to set, crystal formation takes place and the whole mass becomes solid.

HOW TO MIX CONCRETE.

The mixing of the ingredients is simple, but important, and should be carried out as near as possible to the site of the work. First, the proportions to be used must be decided, and then each measured by volume. For example, 1 : 2 : 4 means : To 1 part cement : 2 parts sand : 4 parts aggregate. The sand should be spread on a clean platform, then adding the cement and mixing thoroughly by turning. Next, the aggregate is added, again turning, until the whole mass is moistened. Sufficient water will have been added if, on tamping, a little just flushes to the surface, and the whole mass quivers.

Soft and pliable in the damp state, concrete is easy of manipulation, and in many places where it would be tedious, if not impossible, to use stone, concrete may be substituted with permanent satisfaction.

In the presence of adequate moisture, concrete sets as hard and is as durable as stone, and once properly set it is impervious to moisture, hygienic, fire-resisting, and vermin-proof. It so lends itself to treatment that the finished surface can be made artistic practically to any degree, and it is moderate in price, while the upkeep or annual maintenance charge is practically eliminated. On exposure, concrete really becomes stronger year by year, until it reaches its maximum strength and remains capable of resisting the weather without the application of paint or other preservative.

The safe compressive strength of a 1 : 2 : 4 concrete, when thoroughly set, is about 600 lbs. per sq. in. With modern cements this allows of the factor of safety reaching 6 to 1, or even more. The crushing strain of 1 : 2 : 4 concrete, with modern cements, at 28 days, is about 4,000 lbs. per sq. in. Its tensile strength is only 150 lbs. per sq. in., and to overcome this defect expanded metal or steel reinforcing material is used and varied in strength according to the strain to be sustained.

USES OF CONCRETE.

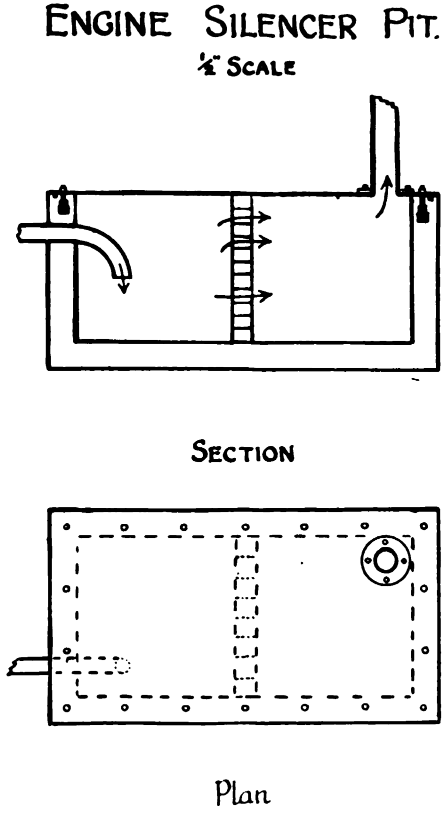
On an estate where mixed farming is practised, concrete might be put to the following economic uses :—

Foundations for buildings ; pillars and bases ; damp proof courses ; floors ; byres ; stables ; dairies ; dung pits and urine tanks ; workmen's cottages ; steps, stairs and plats ; sills and lintels ; sewage tanks ; piggeries ; loose boxes ; silencer pits ; silos ; sheep dippers ; dynamo and engine sheds ; corn bins ; water troughs ; paths ; water supply reservoirs ; weirs ; sluices ; mill lades ;

greenhouses; boathouses and jetties; salmon runs.

The erection of concrete structures requires a certain amount of skilled labour, and there are a few important points to which attention should be paid. Wooden moulds are generally used to keep the concrete in place while it is plastic, and they are so constructed that they may be taken down, properly cleaned, and rearranged on the completion of the work. Care must be taken in making and erecting the moulds, and they should be lightly rubbed with paraffin oil or grease before being set up, to prevent adhesion between them and the concrete. The concrete should be put into the mould within 20 to 30 minutes after mixing, otherwise setting will have commenced, and, to prevent the formation of air pockets, only small quantities should be put into the moulds at a time, and then thoroughly tamped.

No concrete should be laid in frosty weather if that can be avoided, nor should it be laid on dry foundations, otherwise there will be no adhesion between the old surface and the new. Again, the concrete should not be allowed to dry quickly; but should be kept damp for about ten days after laying, when it should be able to withstand traffic.



CONCRETE FLOORS.

For floors in buildings, concrete is an ideal material, and the first essential is a firm and dry foundation. A bottoming of 6 in. of broken stone or gravel, levelled on the surface with smaller stones, in order to economise in concrete, is ideal. On top of this should be laid 3 in. of a 1 : 2 : 4 concrete—of which no part of the aggregate fails to pass through a ring of 1½ in. diameter, and the whole mass rammed solidly to the required levels. Before this has set, another layer 1 in. deep, composed of equal parts of sand and cement, should be applied, and this layer may be finished as desired, with a wooden or steel float, or grooved, as in the case of byres and stables, where the floor should be of a stronger mixture and with aggregate graded from 1 in. downwards. Pieces of rusty, but not scaly, fencing wire might with advantage be inserted in the lower layer to prevent cracking. For barns and granaries a concrete floor is proof against rats, and there is no chance of grain and chaff falling between joints and being swept up later to spoil the purity of the grain samples. For manure sheds such a floor is necessary in order to be able to mix manures satisfactorily. One cubic yard of 1 : 2 : 4 concrete requires 520 lb. cement, 0·43 cubic yards sand, 0·86 cubic yards shingle, in order to get a satisfactory and lasting mass.

Floors should be laid to the proper slopes in order to prevent a flow of water in undesired directions, and a loft floor of concrete must be reinforced. Between the upright supports the reinforcing should be near the bottom surface, but over the pillars between two spans it should be near the upper surface, as it is here that strain is produced. For poultry houses a concrete floor is easily cleaned, prevents lodging of insects, and is rat-proof.

TROUGHS.

Water troughs and hand feeding-troughs may be made to any desired shape and reinforced, otherwise they are liable to fracture. Pigs especially are liable to fracture their troughs through overturning them. Tapered sides in the troughs facilitate the withdrawal of moulds after the material has set.

SILENCER PITS.

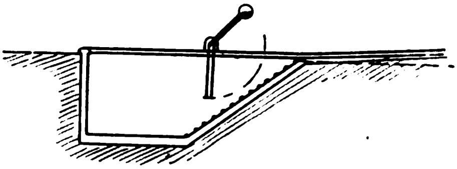
Silencer pits for internal combustion engines, where absence of noise is desired, can be made of concrete. The pit should be dug into the ground, and thus only an inside mould will be necessary. The sides and bottom should be 6 in. thick to withstand alternating pressures, and the pit should be divided by a central partition, placed as shown, in order to interrupt the direct passage of exhaust gases, thus deadening the sound of the explosion. A drain with an outlet into porous ground is sufficient to allow waste oils to percolate away; while a cast-iron lid, with a flange that fits into a groove in the concrete, is bolted down by rag bolts placed in position with a template during the construction of the pit.

SHEEP DIPS.

Sheep-dipping accommodation on a farm is necessary if a flock of sheep is to be kept and dipped at intervals. A farmer can quite well erect a dipper to suit his needs, but he should keep in mind the provisions of the Agriculture Holdings Act before he erects a permanent bath. The real essential in construction is that the bath is sunk practically to ground level but yet is sufficiently high to prevent the ingress of surface water. The sloping portion ought to provide foothold, and the draining area should be constructed so that all surplus dip runs back into the bath. The floor of the area must be grooved, as it is wet and slippery while in use.

Sheep Dipper

¼" Scale



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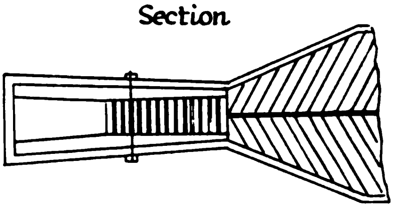


Plan

SILO CONSTRUCTION.

The use of silage is becoming more and more in evidence every year, and some of the advantages that concrete possesses over other materials in this connection are: The silo, if properly made, will not crack and is air-tight; it gives great height for compression, and exclusion of air in the filling process; it is acid proof, and the exuded liquor cannot run to waste; there is little alteration in the concrete due to changes in temperature, and warping does not take place. The inside should be rendered in cement mortar, well floated to present a smooth surface so that little or no resistance to the downward path of the settling silage is offered.

Proper reinforcing enables the height of the concrete silo to be extended up to 50 ft. or more, but 50 ft. is about the limit to which an ordinary blower will raise the silage. Economy of storage space is evident when it is remembered that a circular concrete silo 40 ft. high by 14 ft. in diameter can contain sufficient material to give 60 animals about 35 lbs. each per day for 6 months.

TANKS.

Water reservoirs and settling tanks are most satisfactory when made of concrete because of the fact that it is impervious to water from within and without; it will not rust or decay; it needs no preservative; it requires little attention; and there is no annual maintenance charge. It is hygienic, and offers little lodgment for filth or pathogenic organisms. The shape and size of the reservoirs or tanks must be varied to suit individual needs; but the plan shows a type used in parts of the North of Scotland, where heavy snowfalls can be met better by a semi-circular roof than by a flat one.

Stock cannot climb on to the roof in the event of the enclosing fence being damaged by a heavy snowfall. If provided with a standing waste and with a sloping floor, the reservoir can be flushed out periodically. The walls and top should be respectively 6 in. and 4 in., and the outside—as well as the inside up to above water-level—should be rendered with mortar composed of equal parts of cement and sand.

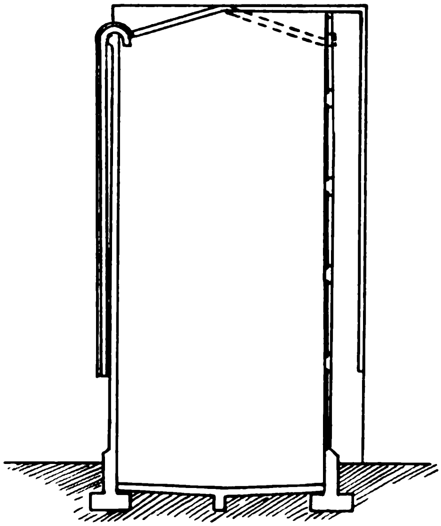
Sewage disposal on farms need present little difficulty, as a septic sewage disposal tank of the type shown is quite effective for an ordinary farm. The sides and bottom are respectively 6 in. and 5 in., while the reinforced top slabs can be 3 in. These should be set, bedded, and pointed in cement, in order to encourage anærobic bacterial action within the tank. If the top is made in sections access can be got to the tank if required. The internal division should also be of concrete with a small central pier to support the covering slabs.

IN THE DAIRY.

For byre and stable fittings concrete offers an ideal material, and it is here, perhaps, that concrete is most valuable to the farmer or the landlord. The initial cost may be high, but the advantage can hardly be denied. Skilled labour, however, is needed if a satisfactory and permanent job is to be the result, but the farmer can provide the unskilled labour for excavating and filling up the bottoming. Care must be taken in the laying of floors and channels, in order that all liquids may drain away quickly.

For dairies concrete is indispensable, as it is easily washed down and has no crevices for accumulation of materials that will negative the attempts at disinfection. The walls of dairies and dairy byres ought to be rendered in cement, and they should be polished smooth

SILO



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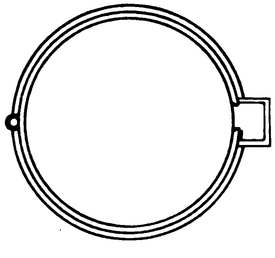
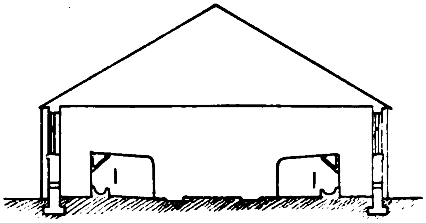


Plan

BYRE



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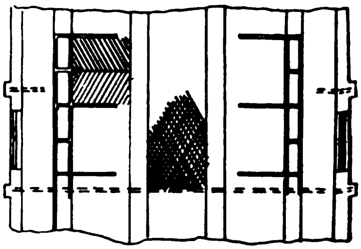
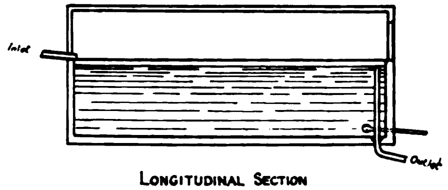
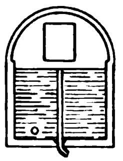


Plan

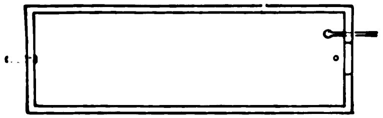
WATER SUPPLY RESERVOIR
¼" SCALE



LONGITUDINAL SECTION

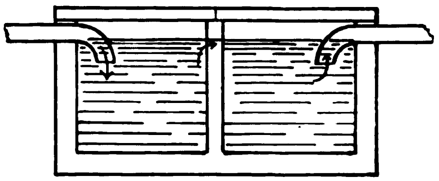


CROSS SECTION



PLAN

SEWAGE DISPOSAL TANK
½ SCALE



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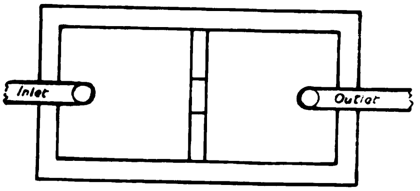


PLAN

without excessive trowelling or floating.

Moulds are required for the erection of feeding troughs and stall divisions, which must be reinforced. The plan shows the section of a double-headed byre with concrete divisions, troughs and floors. All external and internal corners should be rounded off and the floor grooved in diamond or other pattern. Such byres are always in sanitary order, easy to keep clean, and in the event of an epidemic they can be thoroughly disinfected. This cannot be said of floors made of cobbles, as bacteria lodge below dried fæces, etc., and cannot be reached by disinfectants.

OTHER USES.

In addition to those already mentioned concrete can be put to the following uses :—Roof tiles ; refuse pits ; garages and washing areas ; stack foundations ; wells ; garden walls ; loose bottoms for hen coops ; dog kennels ; chimney copes ; culverts ; bridge piers ; manholes ; seats for lathes and saws ; rockeries ; forcing frames ; tabling and ridging ; trap basins ; retaining walls ; sheep footbaths ; fencing posts ; field watering places ; tops of built-in boilers ; incubator houses ; garden path edging ; bridges ; drain pipes and joints ; water channels ; inspection eyes ; culverts for cellar stairs ; winter gardens ; fruit stores ; spawning beds ; grouse watering pans ; summer houses ; clothes poles ; sundials ; tree dentistry ; bulwarking ; artificial ponds ; garden seats ; garden rollers ; ornamental garden vases.

Estate owners will find concrete very useful in situations where exposure to weather is inevitable, such as bulwarking of rivers, creating artificial spawning beds for trout, providing shallow drinking pans on grouse moors, protecting decayed limbs of valuable trees, etc. Where effect is desired the concrete may be tinted to any desired shade, and will fulfil its purpose at the minimum of expense and without offending the sense of the artistic.

The full list of awards in the competition is as follows :—

Section A (for students of agricultural and technical schools).—First prize (£20), D. T. Adam, Ladenford, Forfar. Second (£10), A. J. Carter, Purleigh. Third (£5), E. A. Poulter, Bishops Stortford. Hon.

Mention (£1 each), A. Calder, Aberdeen; J. W. Postings, Wolverhampton; J. F. Wanhill, Muswell Hill; A. J. Dowrick, Truro; W. S. Rogers, Cambridge.

Section B (for all other than students of agricultural or technical schools).—First prize (£20), J. S. Bray, Exeter. Second (£10), A. A. Williamson, Aberdeen. Third (£5), W. J. Pulford, Dorrington, Salop. Hon. Mention (£1 each), F. Hewitt, L. J. Pond, P. E. Wilson, D. Hardy, E. Reddaway.

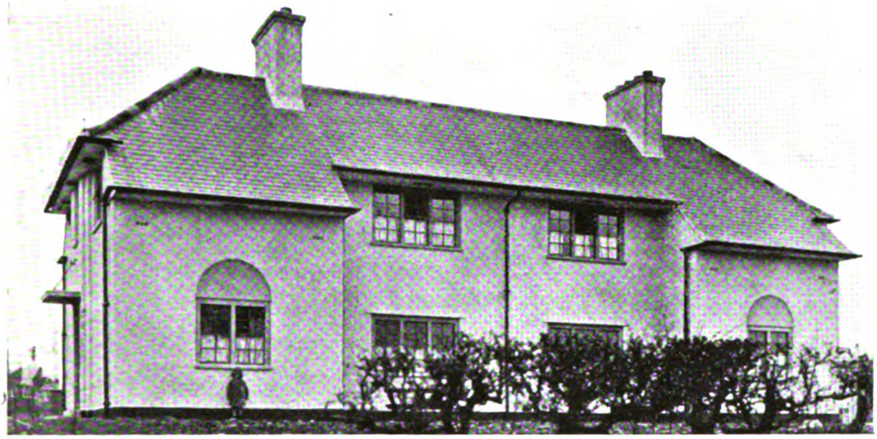
CONCRETE COTTAGES.

As will be seen from our lists of "Prospective New Concrete Work" and "Tenders Accepted" the activities of local authorities in the construction of concrete cottages are increasing. Among others, the Aberdeen Corporation has accepted tenders for the erection of 88 concrete houses; the Northampton Town Council has accepted a tender for the erection of 62 concrete houses; and the Tilbury Urban District Council has accepted a tender for the erection of a further 23 concrete houses.

Many other local authorities are considering the erection of concrete cottages. The Bradford Corporation has received permission to build 200 concrete houses, and the Bristol Corporation proposes to build 300 concrete houses.

There are also many local authorities considering schemes for the erection of working-class houses who have not yet decided as to the materials of construction, including Belfast (200), Bournemouth (100), Burton-on-Trent (53), Cramlington (50), Barnsley Main Colliery Co. (100), Dorking (50), Dover (63), Featherstone (150), Greenock (150), Hastings (106), Leicester (500), Merthyr Tydfil (90), Newcastle-on-Tyne (142), Nottingham (422), Penybont (100), Shoeburyness (34), Wolverhampton (250).

Concrete Gate Posts in Ireland.



CONCRETE COTTAGES AT GRETNA.

NEW METHOD OF COTTAGE CONSTRUCTION.

A NEW type of shuttering, made in small units, has been developed by Messrs. John Laing & Son, Ltd., of Carlisle, and used by them for the erection of a considerable number of concrete cottages, some of which are illustrated herewith. This system is known as the "Easiform," and it is claimed that by its use walls can be built with 8-in. clinker concrete at a cost 20 per cent. less than the current cost of brick walling of the same type.

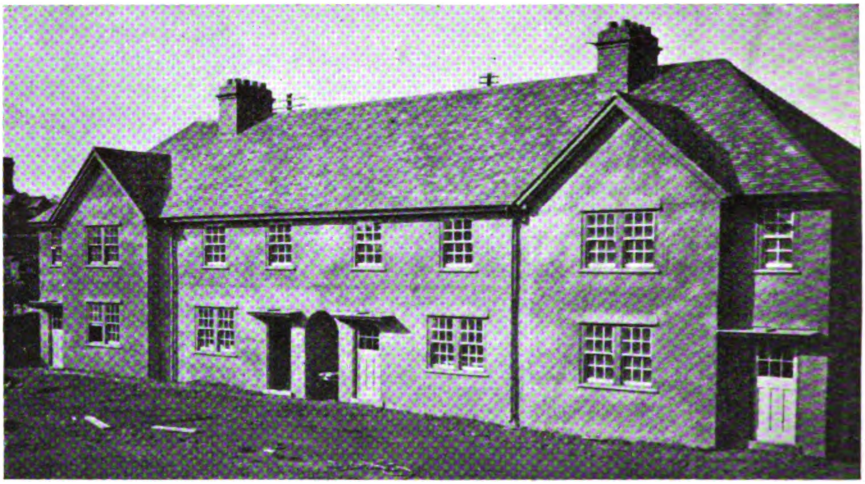
The basis of construction is a light but strong wooden form 6 ft. by 2 ft. by 3½ in. All forms are of standard size except the four corner forms of each block and closures; each form presents a substantial surface to those adjoining, and each is secured to give rigidity and accuracy of position. When the first row of forms is set in position they are filled with concrete and the second row placed on and secured to them and to each other by bolts or pins. The placing and accurate fixing of a pair of forms can be done by two men, under favourable conditions, in one minute. When the second row is filled with concrete, the first is removed and secured on to the top of the second row, thus forming the third course, and this process is repeated up to roof height.

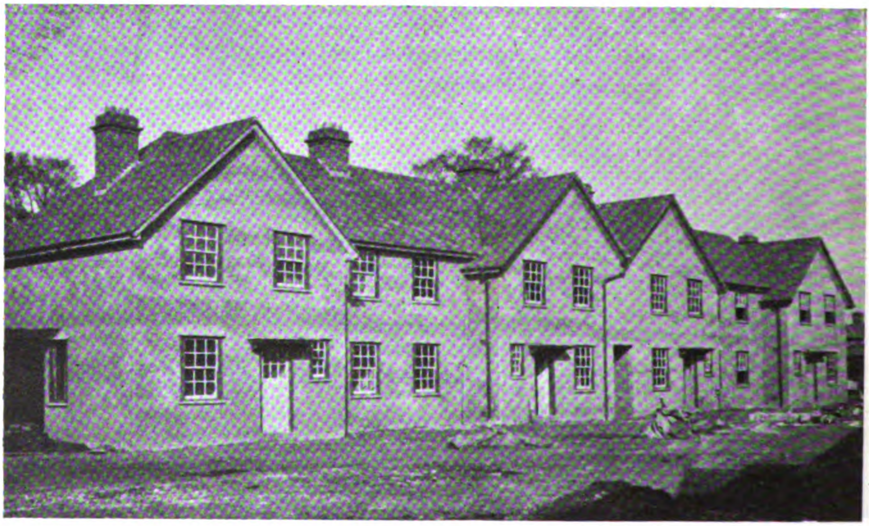
Each course is 2 ft. high, and it has been found that the work is most economically managed when the gang is such that they can complete one round of a block of houses for both shuttering and concrete in a day.

The success of the system depends largely on the method of scaffolding by means of composite uprights and iron putlogs engaging with the shutters, which enables the lifting to be done at the necessary pace without interfering with the construction.

The walls are of cement-concrete wet mixture with a clinker aggregate, finished on the outside with cement render and roughcast; therefore a durable and dry house is ensured, while the light clinker aggregate secures freedom from surface condensation.

We are informed that the only skilled man essential is one working foreman to 12 unskilled men for 4 houses, although it has been found that to have one carpenter to 6 labourers is the most economical, as the carpenter fixes all the windows, window linings and door frames as the work proceeds. By the use of this type of shuttering the architect has the same liberty as in brick construction; any room, door or window can be in any position or of any size desired. It is claimed that 14 days is a liberal time for the building of a block of houses ready for the roof, and that frequently a gang of labourers and two carpenters built the superstructure of four houses in eight working days.

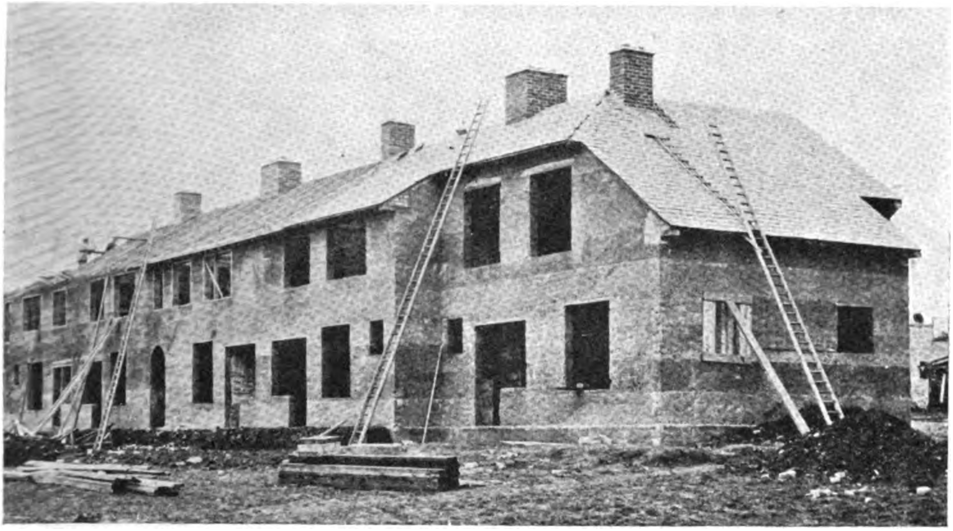


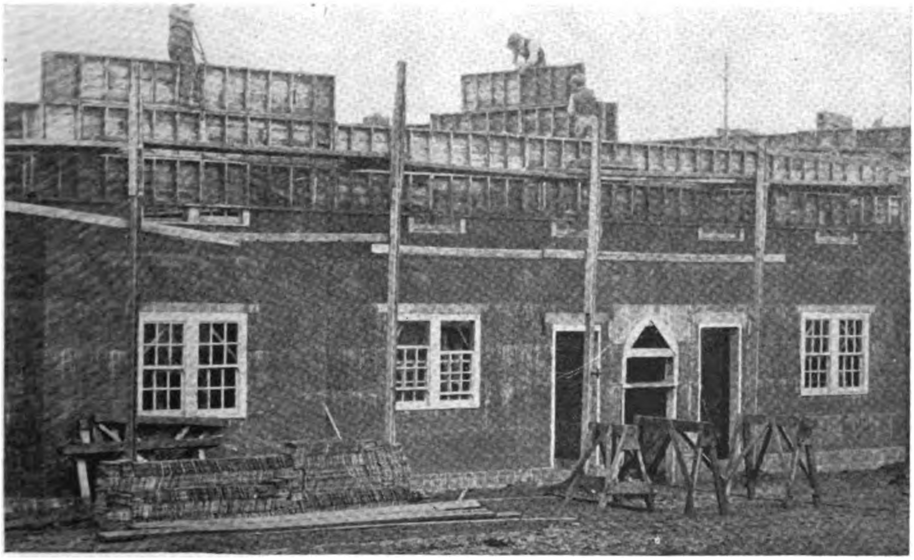


CONCRETE COTTAGES AT HEREFORD.

As to the resistance to heat of this type of wall, Messrs. Laing inform us that they have tested a wall of cinder concrete which contained a considerable proportion of coal and combustible material, by building a chamber of it and using this as a furnace, for three tests of 7 hours each, the temperature being from 500° to 800° Fahr., and the wall was undamaged, being only slightly pitted where pieces of coal were actually on the surface.

It has been found in actual practice that the cost of walling built by this system is 10*s.* per yd. super, as compared with 11*s.* for a 9-in. brick wall in the same district. The cottages illustrated herewith have all been built on this system.





Cottages During Construction.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ½ in. mesh	,,	15	0
Best British Portland Cement	per ton 58*s.* to	63	0
"Ferrocrete" Portland Cement	10*s.* per ton extra		

Boarding for Shuttering—

		Sawn.		*Wrot.*	
		s.	*d.*	*s.*	*d.*
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £24 10*s.* per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £25 10*s.* ,, ,,

Mild Steel Rods for Reinforcement—

		s.	*d.*
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
9/16 in. to ½ in. Rounds	,,	13	6
⅜ in. Rounds	,,	14	6
¼ in. Rounds	,,	15	6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(*Based on Contracts up to £2,000.*)

Portland Cement Concrete well mixed with Clean Water in proportion 1 : 2 : 4—

				s.	*d.*
Do.	do.	in foundation	per yard cube	45	6
Do.	do.	in columns	,, ,,	50	6
Do.	do.	in beams	,, ,,	50	6
Do.	do.	in floor slabs 4 in. thick	per yard super	5	4
Do.	do.	in floor slabs 6 in. thick	,, ,,	7	11
Do.	do.	in floor slabs 9 in. thick	,, ,,	11	6
Do.	do.	in walls 6 in. thick	,, ,,	8	2

(*Add for hoisting* 3*s.* 6*d. per yard cube above ground-floor level.*)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	*d.*
From ¼ in. to ⅜ in.	per cwt.	24	0
,, 9/16 in. to ½ in.	,,	23	0
,, ⅝ in. to 2⅞ in.	,,	22	0

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.*

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.*

Shuttering—

		s.	*d.*
Shuttering and Supports for Concrete Walls (both sides measured)	per square	55	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	51	0
Do. do. in small quantities	per ft. super	0	9½
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last, in narrow widths	,, ,,	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	,, ,,	1	1
Do. do. as last, in narrow widths	,, ,,	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are those current in the London area, namely:—Carpenters and joiners, 1/8 per hour; Labourers on building works, 1/3; Operators on concrete mixers and hoists, 1/4.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

PROSPECTIVE NEW CONCRETE WORK.

Belfast.—*Houses.*—The Corporation proposes to erect 200 houses.

Bilston.—*Tanks.*—The U.D.C. has authorised the storm tanks at the Lunt sewage works to be lined with concrete.

Bournemouth.—*Houses.*—The Corporation proposes to erect 100 houses.

Bradford.—*Concrete Houses.*—The Corporation has received permission from the M.H. to borrow £83,800 for the erection of 200 concrete houses on the Brierly Hall estate.

Bridlington.—Bridge.—The T.C. is considering a scheme for the construction of a bridge over the Gypsy Race.

Bristol.—*Concrete Houses.*—The Corporation Housing Committee proposes to erect 300 concrete houses.

Bromley.—*Concrete Bungalows.*—The R.D.C. has received an application from a local builder for assistance in erecting concrete bungalows at St. Paul's Cray.

Burton-on-Trent.—*Houses.*—The T.C. proposes to erect 53 houses.

Cardigan.—*Road.*—The T.C. proposes to construct a new road along the beach, at an estimated cost of £600.

Chinley.—*Reservoir.*—The Chapel-en-le-Frith R.D.C. proposes to construct a reservoir at Chinley, estimated to cost £5,000.

Chislehurst (Kent).—*Road.*—The U.D.C. has applied to the M.T. for sanction to borrow money in connection with the construction of a new road.

Clacton.—*Groyne.*—The U.D.C. proposes to erect a concrete groyne, estimated to cost £4,000.

Clay Cross.—*Reservoir.*—The U.D.C. has applied to the M.H. for sanction to borrow £20,000 in connection with the construction of a concrete reservoir.

Cramlington.—*Houses.*—The U.D.C. proposes to erect 50 houses.

Cundy Cross.—*Houses.*—The Barnsley Main Colliery Co. has submitted to the M.H. a scheme for the construction of 100 houses.

Dorking.—*Houses.*—The U.D.C. proposes to erect 50 houses.

Dover.—*Road.*—The Corporation has applied to the M.T. for sanction to borrow £45,000 for the construction of a road on the eastern cliffs.

Dover.—*Houses.*—The Corporation Housing Committee proposes to erect 63 houses.

Featherstone.—*Houses.*—The U.D.C. proposes to erect 150 houses on the Purston site.

Greenock.—*Houses.*—The Corporation proposes to erect 150 houses on the Cowdenknowes site.

Harwich.—*Groyne.*—The T.C. has applied to the M.H. for sanction to borrow £2,000 in connection with the construction of a new groyne.

Hollington.—*Houses.*—The Hastings T.C. is considering a scheme for the construction of 106 houses at Hollington.

Keswick.—*Bridge.*—The Cumberland C.C. proposes to construct a bridge at Gretna Bridge, estimated to cost £8,000.

Leatherhead.—*Sewage Works.*—The U.D.C. has applied to the M.H. for sanction to borrow £9,500 for the improvement of the sewage disposal works.

Leeds.—*Road.*—The T.C. has a scheme on hand for the construction of a new 80-ft. road from the Town Hall to Mabgate.

Leicester.—*Sewage Works.*—The T.C. has applied to the M.H. for sanction to borrow £630,703 for the construction of a new sewage disposal works.

Leicester.—*Bridge.*—The T.C. proposes to construct a reinforced concrete bridge over the Fernie Road in place of the existing wooden footbridge.

Leicester.—*Houses.*—The City Council proposes to erect 500 houses.

Logierait.—*Bridges.*—The Perth C.C. proposes to construct three bridges at Logierait, at an estimated cost of £5,210.

Luton.—*Bridge.*—The Welwyn R.D.C. proposes to construct a bridge over the London and North Western Railway, estimated to cost £4,000.

Merthyr Tydvil.—*Bridge.*—The T.C. has applied to the M.T. for sanction to borrow £11,000 for the construction of a ferro-concrete bridge at Pontyclun.

Merthyr Tydfil.—*Houses.*—The B.C. are preparing a scheme for the construction of 90 houses.

Newcastle.—*Houses.*—The Housing Committee proposes to erect 142 houses on the Walker Estate.

Newton Abbot.—*Concrete Road.*—The U.D.C. has received sanction from the M.T. to borrow £1,055 for the construction of a reinforced concrete roadway in Market Square.

Nottingham.—*Houses.*—The City Council has approved of the plans of the

Housing Committee for the construction of 422 houses on the Sherwood estate.

PENMAENMAWR. — *Road.* — The M.T. has prepared plans for the construction of a new road between Penmaenmawr and Llanfairfechan, estimated to cost £100,000.

PENYBONT.—*Houses.*—The R.D.C. has applied to the M.H. for sanction to erect 100 houses.

PRESTON.—*Road.*—The Lancashire C.C. has applied to the M.T. for sanction to borrow £40,000 for the construction of a new road at Todmorden.

SHOEBURYNESS.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to erect 34 houses.

STAFFORD.—*Houses.*—The British Reinforced Concrete Engineering Co., Ltd., have applied to the Housing Committee for a loan of £50,000 to enable them to construct 60 houses for the occupation of their staff.

STOCKINGFORD.—*Sewage Works.*—The Nuneaton T.C. has applied to the M.H. for sanction to borrow £4,000 for sewage disposal works at Galley Common, Stockingford.

SWANAGE.—*Sea Wall.*—The U.D.C. has applied to the M.H. for sanction to borrow £1,700 in connection with the alterations to the sea wall.

TORQUAY. — *Platform.* — The Devon Main Roads Committee has agreed to the construction of a concrete platform 100 ft. in length on Torre Abbey Sands, at an estimated cost of £2,000.

WAKEFIELD.—*Sewage Works.*—The City Council has applied to the M.H. for sanction to borrow £33,000 for the improvement of the sewage disposal works.

WATFORD.—*Road.*—The Towns Improvement Committee is considering a scheme for the construction of a new road from High Street to Watford West.

WOLVERHAMPTON.—*Houses.*—The Corporation Housing Committee proposes to erect 250 houses in Willenhall Road.

TENDERS ACCEPTED.

ABERDEEN. — *Concrete Houses.* — The Corporation has accepted tenders in connection with the erection of 86 concrete houses, estimated to cost £41,304.

BARNSLEY.—*Sewage Works.*—The T.C. has accepted the tender of Messrs. Hodkin & Jones, at £523, for the reinforced concrete work at the sewage works.

BRIDLINGTON.—*Sea Walls.*—The T.C. has accepted the tender of Messrs. J. T. Levitt, Ltd., at £53,123, for the construction of a new sea wall, promenade, groynes, etc.

CARLISLE.—*Bridge.*—The City Council has accepted the tender of Messrs. M. Muir & Co., Ltd., Kilmarnock, at £12,120 7*s.* 4*d.*, for the construction of four concrete arches over the River Caldew and Little Caldew to carry the proposed widening of the highway.

CARLISLE.—*Piers.*—The T.C. has accepted the tender of Messrs. J. & R. Bell for the construction of concrete piers and abutments for the footbridge over the river Caldew.

CHAPMANSFORD.—*Bridge.*—The Whitchurch R.D.C. has accepted the tender of Mr. W. Knight, Andover, at £123 13*s.* 10*d.*, for the construction of a reinforced concrete bridge at Chapmansford.

CYMMER. — *Bridge.* — The Glyncorrwg U.D.C. has accepted the tender of Mr. J. Sutherland, Abercynon, at £10,342 16*s.* 3*d.*, for the work required in the construction of a reinforced concrete bridge at Cymmer.

DERBY.—*Bridge.*—The County Council has accepted the tender of Mr. G. F. Tomlinson, Derby, at £30,862, for the construction of a ferro-concrete bridge over the Dove on the Derby-Burton Road.

DUNMOW.—*Sewage Works.*—The R.D.C. has accepted the tender of Mr. Barry, at £1,044, for the construction of sewage works at Felstead.

FRASERBURGH.—*Slipway*—The Harbour Commissioners have accepted the tender of Messrs. J. Sangwin & Son, Cricklewood, N.W.2, at £6,066 4*s.* 4*d.*, for concrete work in connection with the construction of a slipway at Faithlie Harbour.

GLASGOW.—*Terracing.*—The T.C. has accepted the tender of Messrs. H. Macpherson & Co., at £632 17*s.* 7*d.*, for constructing in concrete the terracing for the bandstand at Alexandra Park.

GUILDFORD.—*Retaining Wall, etc.*—The T.C. has accepted the tender of Messrs. W. Stevens & Sons, at £1,250, for the construction of a concrete retaining wall, and underpinning two piers at Depot Yard.

HAYWARDS HEATH.—*Reservoir.*—The Mid-Sussex Joint Water Board has accepted the tender of Messrs. Gray's Ferro Concrete Co., Glasgow, at £2,219 2*s.* 8*d.*, for the construction of a reinforced concrete reservoir of about 200,000 gallons capacity.

KINGS LYNN.—*Bridge.*—The Norfolk C.C. has accepted the tender of Messrs. K. Holst & Co., at £21,500, for the construction of a reinforced concrete bridge at Kings Lynn.

LONDON.—*River Embankment.*—The Stepney B.C. has accepted the tender of Messrs. D. G. Somerville & Co., Ltd., at £34,484, for works in connection with the extension of the river embankment for a distance of 77 ft. eastward and 36 ft. westward of the existing embankment, and erecting in the river a reinforced concrete island, 168 ft. long and 35 ft. wide with its deck 11 ft. above high-water level, and 32 ft. above the foreshore.

MANCHESTER.—*Flags.*—The Corporation has accepted the tenders of the Premier Artificial Stone Co. and Mr. A. Tetlow for the supply of concrete flags.

MONIFIETH.—*Bridge.*—The T.C. has accepted the tender of Mr. C. Dick, Monifieth, at £925, for the widening of Milton Bridge in reinforced concrete.

NORTHAMPTON.—*Concrete Houses.*—The T.C. has accepted the tender of Messrs. W. Higgins, Ltd., Northampton, at £31,244, for the erection of 62 concrete houses.

PENRITH.—*Reservoir.*—The U.D.C. has accepted the tender of the Cumberland Reinforced Concrete and Artificial Stone Co., at £6,150, for the construction of a concrete reservoir.

ROCHDALE.—*Bridge.*—The B.C. has accepted the tender of Messrs. R. & T. Howarth, Rochdale, for the construction of a ferro-concrete bridge over the River Roch at Hamer.

SALTCOATS.—*Sea Walls.*—The Corporation has accepted the tenders of Mr. J. Bannatyne, Irvine, at £950 12*s.* 6*d.*, for the construction of a concrete wall, £1,501 19*s.* 3*d.*, for the construction of concrete terracing and concrete retaining wall.

SOUTHEND-ON-SEA.—*Sewer Pipes.*—The T.C. has accepted the tender of Messrs. J. Ellis & Son, for the supply of large concrete pipes for sewers for the Fairfax Drive Valley.

TILBURY.—*Houses.*—The U.D.C. has accepted the tender of Mr. E. Washam, at £11,360, for the construction of 23 concrete houses.

RECENT PATENT APPLICATIONS.

195,096.—F. Kallinger and F. Reger: Concrete foot for masts or poles.

211,517.—H. Andrews: Manufacture of Portland cement.

211,899.—P. Pench: Machines for moulding concrete blocks.

211,947.—A. A. Thornton (Naamlooze Vennootschap Korrelbeton Maatschappij voor Woningbouw in Porenze Beton): Walls, floors, and roofs of unrammed concrete.

211,948.—W. Hopkins: Mechanism for vibrating and consolidating concrete within moulds.

212,298.—M. Vogel-Jorgensen, E. Ronne and K. Middelbor: Process and apparatus for the utilisation of the combustion gases from rotary cement burning kilns.

212,321.—D. Davidson: Reinforced-concrete structures.

212,328.—Major & Co., Ltd. and W. Sangwin: Reinforced-concrete road foundations.

212,419. J. A. Erikson: Method of manufacturing a porous material from Portland cement.

212,474.—K. Walter and O. Henkel: Concrete linings for tunnels.

212,477.—F. Bodson: Construction of concrete structures.

213,744.—H. W. Cowling: Concrete railway sleepers.

214,035.—C. Kearton: Concrete hoppers.

214,180.—F. J. J. Fowler & Co. (Leeds), Ltd. and C. M. Wilcock: Apparatus for mixing concrete.

214,369.—B. Bakewell: Manufacture of magnesite cement.

214,482.—A. Hiley, H. T. Garvie and E. Le Bas: Loading-skips for concrete mixers.

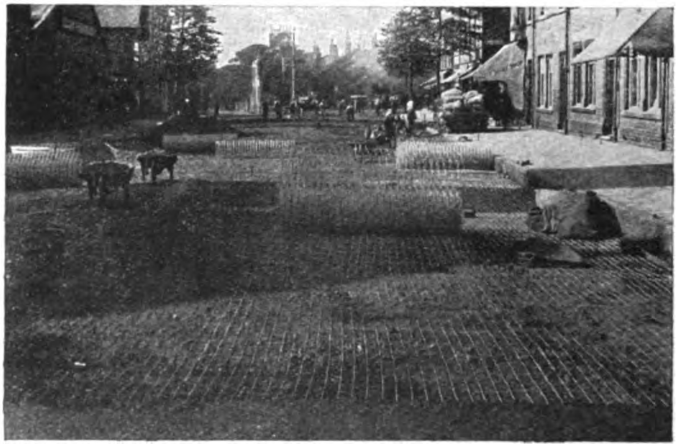
TRADE NOTICES.

A record of achievement of which they might well be proud is contained in a book issued by Messrs. Trollope & Colls, Ltd., the well-known firm of builders. Well printed, strongly bound, and illustrated with a selection from the numerous large public and other buildings which the firm has erected, this volume is very much more than the usual catalogue; a collection of illustrations of the works of any large firm of building contractors is largely a record of current architecture, and the opportunities Messrs. Trollope & Colls have had of carrying out the designs of many of the leading architects of the day make this book a valuable addition to the library of any architect —although, if any criticism may be made of such an excellent production, it is that it is too large to find a place on the ordinary bookshelf.

Messrs. David Weston & Co., Ltd., of 46, High Street, Croydon, have sent us a copy of the first of a series of pamphlets they propose to issue dealing with the roads problem. The series is entitled "The King's Highway," and the copy before us, entitled "The Economy of Concrete Road Construction," points out the advantages of the concrete road from different points of view and gives figures showing the cost of a concrete road compared with water-bound macadam.

Mr. H. W. Darby, formerly Secretary to the Walker-Weston Company, has been appointed Secretary to Messrs. David Weston & Co., Ltd., 46, High Street, Croydon.

In our notice of the exhibit of Messrs. John Fowler & Co. (Leeds), Ltd., at the Building Trades Exhibition in our last issue it was stated that the capacity of their well-known mixer was a batch every 40 minutes; this should, of course, be read "a batch is thoroughly mixed in 40 seconds."



REINFORCED CONCRETE ROAD AT CHESTER.

[This is a Class 1 road, with an average width of 39 ft. The concrete is 8 in. thick reinforced with "Maxweld" reinforcement supplied by Messrs. Richard Hill & Co., Ltd., of Middlesbrough.]

Single Copies, 1*s.* 6*d. nett.* *Annual*, *Post Free*, 18*s.*

CONCRETE AND CONSTRUCTIONAL ENGINEERING

JULY 1924 VOL. XIX. No. 7

A MONTHLY JOURNAL for Engineers, Architects, Surveyors and Contractors and all interested in Cement, Concrete, Reinforced Concrete, Fire-Resisting Construction and Structural Steel.

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No. 200

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Estd. 1809.

BY APPOINTMENT TO
THE LATE KING EDWARD VII

BY APPOINTMENT TO
H.M. KING GEORGE V

LEAD SEALED
PELICAN
BRAND
OF
EARLE'S
CEMENT

MANUFACTURED BY
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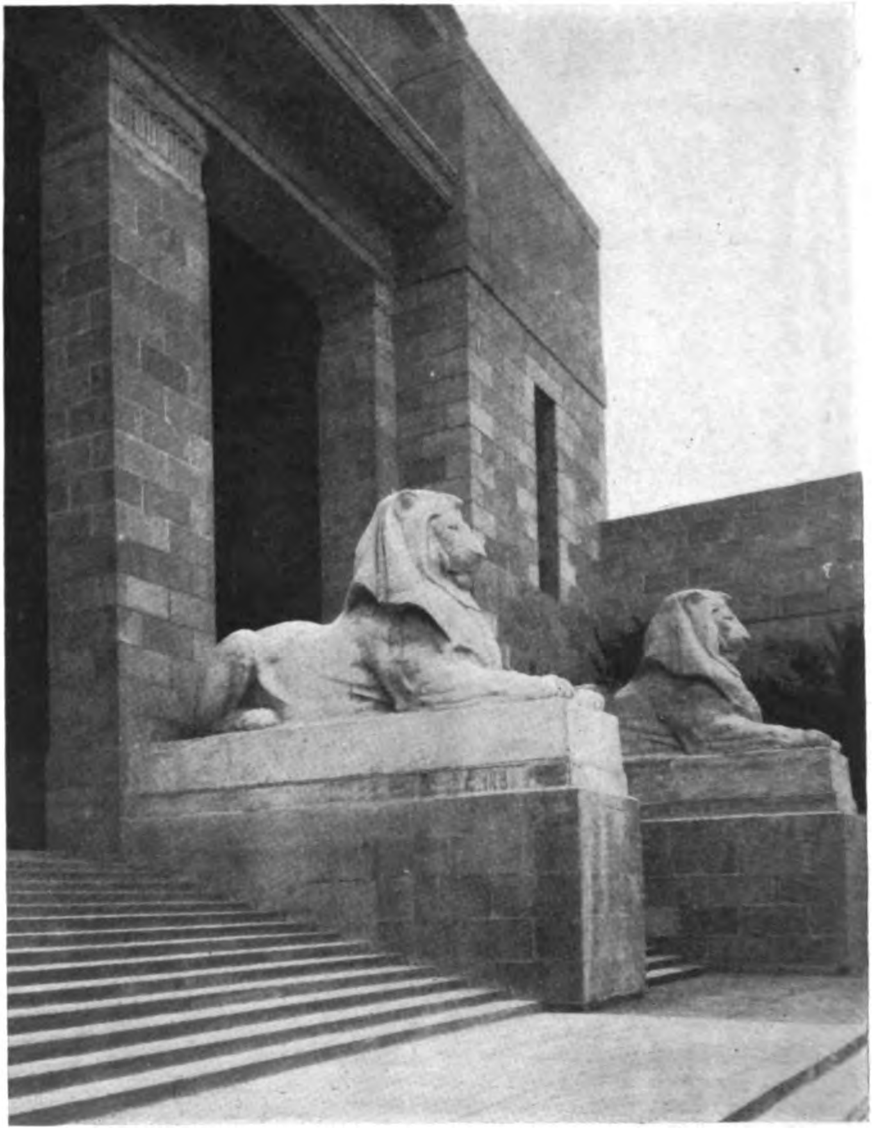
WILMINGTON,
HULL.



BRITISH EMPIRE EXHIBITION: CONCRETE LIONS AT ENTRANCE TO H.M. GOVERNMENT BUILDING.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

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EDITORIAL NOTES.

THE EXHIBITION.

IT is appropriate that the British Empire Exhibition should come into being in the year which marks the centenary of the invention of Portland cement, the material with which it is chiefly built. It is fortunate that concrete has been used for the construction of these monumental buildings in this country, where the public have previously not had an opportunity of seeing what can be done with the material as they have in other countries where concrete is more used for all kinds of buildings. Above all, we welcome the connection between the buildings and their purpose, the housing of the largest exhibition the world has ever seen, an exposition of the life and products of the whole of the British Empire, which has already been seen by about 5,000,000 people. Better propaganda for a more extended realisation of what is possible in concrete building could hardly be imagined, yet the scepticism with which propaganda by trade interests is liable to be looked on is absent. For such a purpose the buildings had to be of enormous size ; they had to possess a pleasing appearance, as befitted buildings to contain the products of the greatest Empire of all time ; they had to be built as cheaply as possible in a permanent material ; they had to be erected to a time-table which but few thought the contractors would be able to keep to. And after considering all available materials, the architects and the engineer decided that concrete best met these various requirements, and in spite of strikes and the unforeseen delays unavoidable in such a vast enterprise the Exhibition was completed with the exception of one or two finishing touches and opened on the appointed day.

Although there have been criticisms, as all new buildings are criticised, since the Exhibition was opened, nowhere have we seen or heard anything which suggests that the buildings might have been better built in another material. In the early stages doubts were expressed in many quarters as to whether concrete would fulfil all that was expected of it, but this general recognition, after the completion of the work, and bearing in mind all the limitations of time and cost, that concrete has proved the most suitable, if not the only, material in which the buildings could have been carried out is, we think, of supreme importance to the future of concrete building in this country. Criticism, and there has been much of it, has concentrated on design, and it has to be said that the favourable comments of the architectural press and those qualified to express an authoritative opinion on architectural matters have far outnumbered the adverse critics. There can be no finality in art, no set rules of architecture which can be applied to every building. It is generally found that innovations in architectural design and departures from tradition receive more adverse criticism than favourable, and it is rather a matter for surprise, and a great compliment to the architects, that the buildings at Wembley, the first attempts at monumental architecture in reinforced concrete in this country, should have been so well received. One could almost have wished for more criticisms embodying suggestions for improvement, for no one supposes that Wembley represents the last word in concrete architecture. It is the first in this country, and if this is to be considered the beginning of a style for concrete architecture in the future it is certainly starting under more favourable conditions than the first prehistoric attempts at forming shelters of wood and stone which laid the foundations of the Greek and Classic styles of stone architecture.

No one doubts the practicability of using reinforced concrete for almost any type of building, or its economy, or the ability of modern architects to design buildings using the material to the best advantage and at the same time producing pleasing effects of proportion, mass, light and shade. The chief difficulty, and the point made most of by the critics, is the surface texture. The marks left by the shuttering are called pleasant by some and ugly by others, but this could easily be overcome, according to the taste of the architect, by using metal shuttering and cleaning down the surface if it is required to be smooth, or by using shuttering of such a shape as to leave a pattern on the surface if such be preferred. The uniform grey colour is, however, unavoidable unless special steps are taken, at a small extra cost, to obtain some relief. At Wembley there may be seen examples of many different methods of surface treatment, such as exposing the aggregate by removing the film of cement from the surface, mixing different materials with the cement to give colour effects, and coating the surface with special paints. Considerable attention is now being given to this question, and we now have, in the centre of London, in the Fortune Theatre, an example of an exposed-aggregate façade, but there is much to be done both in research and educational work before we evolve a method which will at small expense produce a concrete surface which by its texture alone will be pleasant to the eye and impart an added interest to a building. The lights and shades resulting from the disposition of the masses give a certain relief, as may be seen in the towers of the Stadium, but the flat grey of concrete when used for wall surfaces which are unbroken or only slightly relieved needs something more if it is not to present a dull and monotonous appearance. With a plastic material set in moulds it is obvious that any elaborate departure from the straight line, involving complicated moulds, adds to the cost, and it is probable that a satisfactory method of producing an attractive surface which would make a flat wall as pleasing as one relieved by pilasters and cornices and imitation voussoirs would give the desired result at less cost. The necessity for concentration on surface treatment is one of the outstanding lessons to be learnt from the Exhibition.

CONCRETE ROADS AND SLIPPERINESS.

As the Minister of Transport truly said in the House of Commons the other day, modern traffic demands a smooth and durable road surface, but we do not agree with him when he said "a slight degree of slipperiness in certain states of the weather was part of the price we had to pay" for such roads. The anxiety of members of Parliament to secure the best possible roads is to be heartily welcomed, but there seems to be considerable confusion of thought on the subject. The question which gave rise to Mr. Gosling's remarks quoted above asked whether the Minister of Transport's attention had been called "to the grave risks run by all motor traffic travelling on the new concrete roads in wet weather, and whether in view of this danger to the public he would consider the question of cancelling contracts for such roads and substituting therefor contracts for roads with a less slippery surface." It is quite clear from supplementary questions, however, that the roads complained of were not true concrete roads at all, and that the trouble was due to the slipperiness of the tar or asphalte surface with which the concrete foundations were covered. Before asking questions of such a nature containing suggestions likely to retard the development of the best type of road and thus defeat the very object those asking the questions have in view, it is to be regretted that more trouble is not taken to ascertain the facts. If the road surface had been examined the question would probably have requested the Minister to endeavour to prevent the surfacing of concrete roads with slippery materials!

Further lack of knowledge was shown when the same member asked whether the Minister of Transport "would consider treating the surfaces [of roads] in the same way as is done in the United States of America"—when the actual fact is that the excellence of the road surfaces which visitors to America speak so highly of is solely due to the fact that they are not covered in any way. It has been realised in that country that the very nature of the materials of which concrete is made is an assurance against slipperiness, for the broken stone and sharp sand is in itself gritty. We would recommend those who are in doubt as to the non-slipperiness of a bare concrete surface to motor over one of the many all-concrete roads now built in this country, first making sure that they have not been convered with an asphalte or tar surface. They would then have the same experience as the transport manager of one of the firms possessing a large fleet of motor vans operating in London, who, speaking at the recent Bristol Congress of the Institute of Transport, said he had motored frequently over the unsurfaced-concrete section of the North Circular Road at Wembley: "He had watched buses operating over it, and also extremely heavy lorries, and he had motored over it himself and found it fine. He had tried to skid his car on it, but had not been able to do so even on a wet day. It was an excellent form of surface."

THE BRITISH EMPIRE EXHIBITION AND ITS CONCRETE BUILDINGS.

By WILLIAM HARVEY.

"Art for art's sake," though preached by a group of exceptionally brilliant artists, never became a popular theme with the Briton, and by thousands of visitors the British Empire Exhibition at Wembley will be appreciated purely as a place where a vast collection of useful commodities has been amassed and stalled for convenient inspection. Architectural style in the buildings housing the really wonderful exhibits will perhaps be accepted without much comment by many, and so long as the various individual objects are visible and the Exhibition grounds are easily accessible the main object will be achieved. From the architect's point of view, however, the whole place is of absorbing interest.

[*Mr. Gilbert Bayes, Sculptor.*

"The Art of the Garden."

Clay Mould of Cement Plaque at the British Empire Exhibition.

Dominions and Colonies of the Empire are scattered in different zones of the earth's surface, and differ from one another intensely in the matter of climate and scenery. Types of architecture more or less appropriate to each climate have been evolved locally, and it was distinctly desirable that characteristic examples should be selected for the purposes of the Exhibition even at the cost of possible incongruity in the assembling of violently conflicting styles upon adjacent sites. Minaret and dome and tapering pagoda, mud walls and masonry, are seen in a single glance, and from the Imperial point of view it is fitting that these bizarre conflicts of style should exist. Nothing could be imagined more likely to bring home to the untravelled Briton the extent and resources of the Empire than the realisation that England herself is but a corner of it. And the more his attention can be directed to the special beauties of other parts of the Empire, the more likely is this result to be achieved. Whether the present arrangement of pavilions is intended as a purposeful expression of the suggestion underlying Kipling's lines,

> "What should they
> know of England
> Who only England
> know ?"

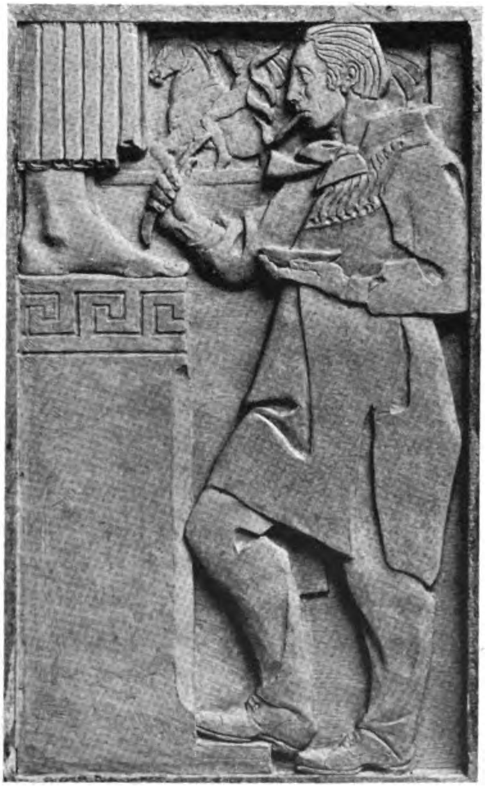
the thought certainly finds some degree of recognition in the juxtaposition of buildings typical of different countries and races brought together under British Rule.

It seems probable that this idea might have been developed still further had the impression received from the contrasts of single buildings been reinforced by more systematic grouping of pavilions of similar style. The Imperial aspect would not have suffered and the artistic side would have gained immensely if the architectural styles and colours had been collected into recognisable groups.

The fine pavilion in Moghul style representing India is satisfactorily associated with two other Oriental kiosks, but the brown Burmese buildings with their fretted woodcarving intervene between the white walls of India and the white walls of East Africa and the domed building, also coloured white, representing Palestine and Cyprus. Had the styles of Saracenic architecture been kept together the impression would undoubtedly have been far finer than it is. The Burmese group, equally beautiful after another fashion, would have found a more sympathetic setting had it been included with the kindred concave-roofed buildings of Ceylon and Hong-Kong. Malaya, planted in a corner between the Renaissance architecture of the Australia and New Zealand buildings, might also have taken its place in the Indo-Saracenic school if a certain amount of revision in the colour scheme had been permissible. The group idea has been carried out in the "mud" walled buildings of Nigeria and the Gold Coast, and these buildings gain an impressiveness out of all proportion to the cost of their erection by that simple fact. In spite of their plainness and crudity they are eminently satisfactory.

But, accepting the colours of the pavilions representative of native styles just as they are, there was surely no need to tint the buildings designed in frankly European style in tones of white, cream and buff just sufficiently differing from one another to suggest inconsistency and lack of control in the very heart of the Exhibition, and make the more substantial concrete buildings look less bright by contrast ?

The lack of any united colour scheme in the modern group and the minor kiosks surrounding the lake is very noticeable. If bright colours and a free display of fancy were permissible in some of the smaller stalls these things should have been encouraged in the Dominion and Commonwealth buildings which would have been neither more nor less representative of Canada and Australia if decorated in harmonious polychrome than they are at present when covered with two misfit washes of monotone. Colour in architecture has been canvassed somewhat of late years, and should the rumour that the Exhibition will revive next year prove to be a true one, a competition for providing it with an adequate colour scheme would join together two matters possessed of intrinsic interest.



[*Mr. Gilbert Bayes, Sculptor.*

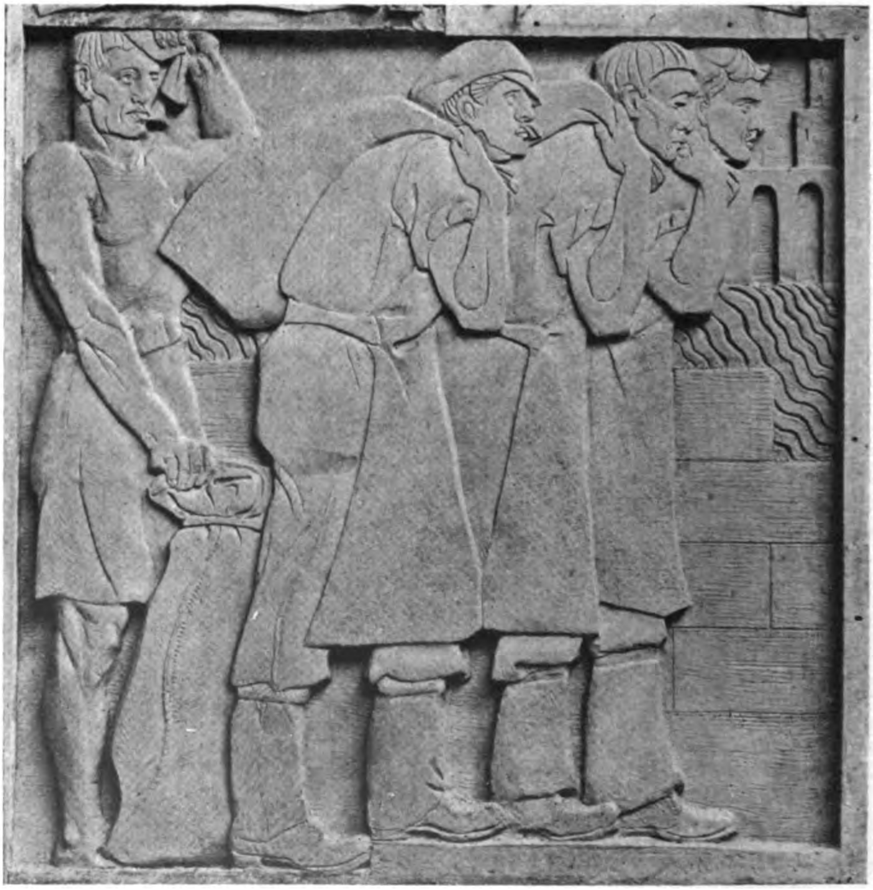
"THE SCULPTOR'S ART."

CLAY MOULD OF CEMENT PLAQUE AT THE BRITISH EMPIRE EXHIBITION.

[Actual size 4 ft. 4 in. by 2 ft. 7 in.]

Two lengths of colonnade with the concrete-built block of Lloyds Bank in the centre somewhat unaccountably blot out the central vista and at a distant point, just beyond the lake, *The Times* building also stands astride the central axis and with its bright yellow buff and its more minute style of architecture, clashes with the great grey front of the Stadium. Such a central and honourable position might well have been reserved for H.M. Government Building which is now situated in a sort of backwater near the Amusements Park, and is approached from the principal courts by a side track to the south of the India pavilion and by a narrow though charmingly old-fashioned bridge across the railway track. The Government building is grey, but stands among the white-fronted buildings representing the West Indies, Newfoundland and Fiji. This side of the Exhibition might reasonably have been reserved for the Far Eastern group of buildings since their unusual style agrees with nothing else in the Exhibition.

The more permanent constructions include the entrances, H.M. Government Building, the Palace of Arts, the Palaces of Engineering and Industry and the Stadium, the hydraulic supply house, and the bridges across the lake. These are all built of concrete, and the whole Exhibition is a triumph for this material. Concrete as a material of construction is no longer in the experimental stage, and its use at Wembley has been dictated in most instances by purely practical considerations. There has been no fine imaginative scheme for exploiting the resources of concrete and letting the world see what prodigies of architecture could be achieved by its means. Perhaps its use in the Exhibition without the best advantage having been taken in the lay-out is a more impartial testimony to its effectiveness. Advocates of concrete construction will be able to visit Wembley and point out a thousand and



[*Mr. Gilbert Bayes, Sculptor.*

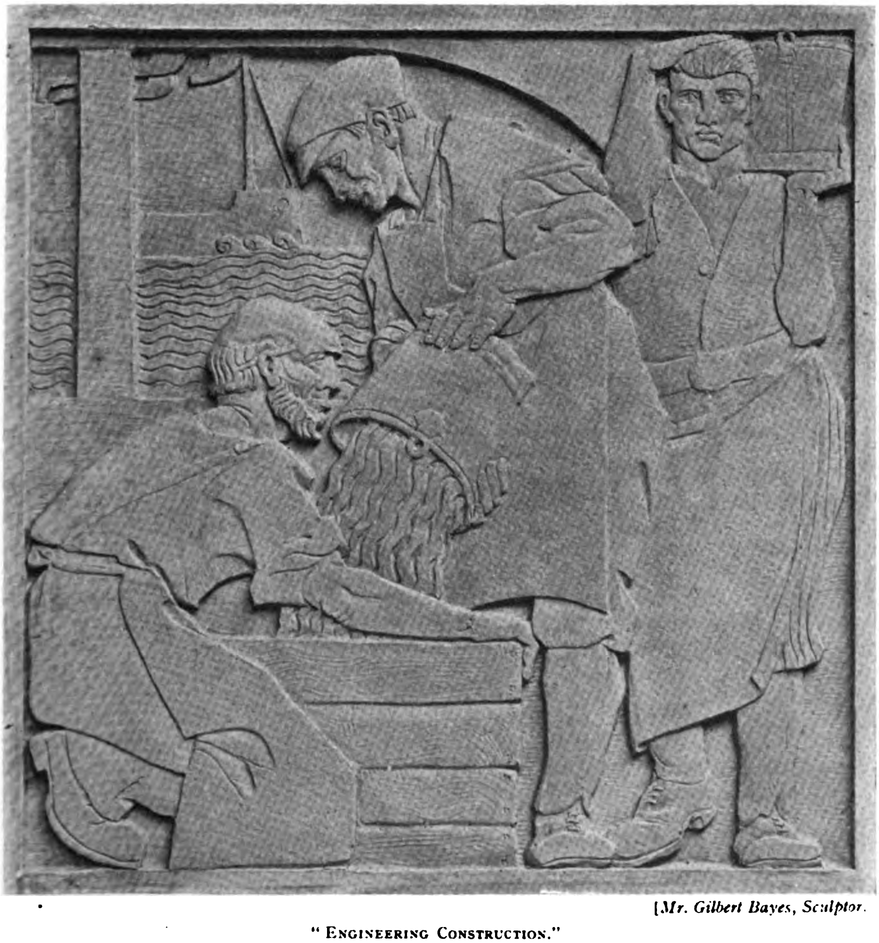
" BUILDING."

CLAY MOULD OF CEMENT PLAQUE AT THE BRITISH EMPIRE EXHIBITION.

one instances where more could have been made of the opportunities it presents had systematic attention been given to it in the planning. Even as it is its adaptability is demonstrated beyond the possibility of a doubt.

The design of temporary buildings for an exhibition does not in reality afford the opportunity it seems to offer for experimental research in new forms of construction. Limitations in cost and time, for speed of erection has to be considered as well as money, prevent any extraordinary devices being employed, and if concrete has been largely used for many different purposes it is because experience has established it as an ordinary and not an extraordinary building material.

Pre-cast concrete blocks and *in situ* work were used in different buildings as the occasion arose, and suggestive differences of treatment are observable in consequence. In the matter of design even more variety exists than in the execution. The structural properties and possibilities of different classes of concrete, plain and reinforced, are becoming known, but architecture has not yet assimilated the information. This hesitation as to what is reasonably permissible is exemplified in the concrete covered walk adjoining Lloyds Bank, where the



[*Mr. Gilbert Bayes, Sculptor.*

"ENGINEERING CONSTRUCTION."

CLAY MOULD OF CEMENT PLAQUE AT THE BRITISH EMPIRE EXHIBITION.

[Actual size 4 ft. 4 in. by 4 ft. 3 in.]

square piers are spaced at close, moderate and extremely wide intercolumniations in the same short length of colonnade.

The classic tradition dies hard, and though one aspect of concrete work would class it with the continuous homogeneous walled and domed styles of the East, the facilities for shuttering straight-sided masses have conspired with the recent revival of Greek style to guide concrete design in the direction of the post and beam architecture of classic times.

As in the case of the span, the thickness of pier to support a load is extremely variable, and it is possible to see at Wembley small piers supporting beams over wide spans near larger piers placed close together and supporting far less weight in an adjacent part of the same architectural group. Where a large range of spacing is made structurally possible by the insertion or omission of reinforcement, consistency in design can only be achieved by watchfulness on the part of the architect who must compose, as a sculptor does his plastic masses, by using an eye well trained to discern pleasing arrangements of contour and light and shade.

In spite of some pardonable inconsistencies of this kind (which, by the way, another critic would be quite entitled to call pleasant variations), the concrete buildings surrounding the entrance garden are very effective. Large moss-covered baskets of flowers hung in the intercolumniations of the colonnade carry the colour note into the grey, while lamp standards crowned with geographical globes of opal glass stand out grey among the flowers and greenery of the garden.

The Palaces of Engineering and Industry are fronted towards the central avenue, or Kingsway, with massive square piers supporting an architrave and a parapet high enough to screen the pitched roofs from the view of persons standing on ground level. From higher points, such as the Stadium terrace, this device fails, of course, and it is to be hoped that a tidy method of flat roofing with dignified lantern light clerestories may soon come into fashion both for Exhibitions and for ordinary purposes. It will be introduced eventually as reinforced concrete comes to be used systematically, but the point is to get it while we are alive to enjoy the improvement.

A series of concrete flag-poles supported in concrete lion's-head sockets projecting from the faces of the parapets carries a wealth of bunting that relieves the monotony of the extreme length of these buildings. Their lake fronts are even more interesting, for a projecting lower story is provided with a flat roof which serves the purposes of an open-air café and adds human interest and animation.

In the interiors concrete construction has also been adopted, but the large piers and flat lintels of the exterior give place to slender tapering supports and beams whose soffits have been given a segmental camber. Large spans at the junctions of principal alley-ways are bridged by concrete arches.

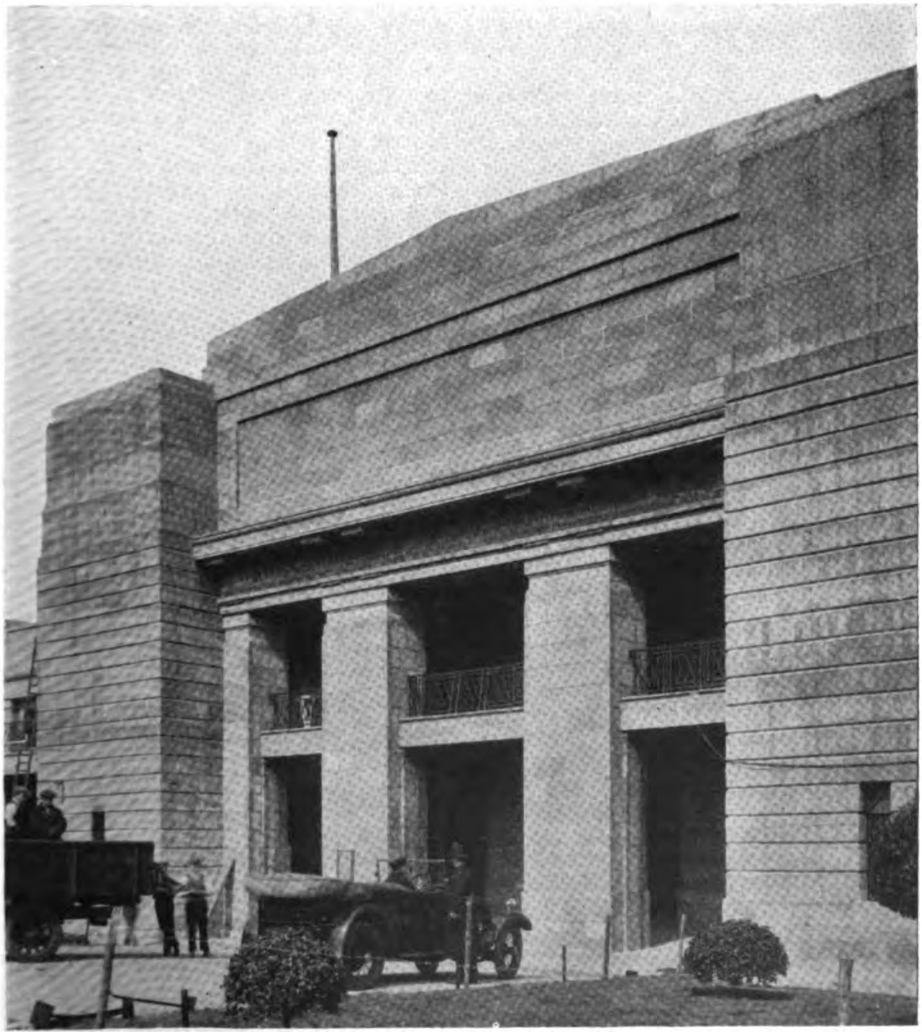
Steel is freely used in the upper parts of the buildings in carrying pitched roofs of tie-bar type, of which the central parts are glazed. The purposes of the buildings have been given full consideration. The spans are large and the floor space as unobstructed as possible. The interior effects are severely utilitarian, and though the direct adaptation of design to purpose imposes a certain air of sincerity that preserves the buildings from insignificance, their plain nature forbids any real grasp of the immense scale or realisation of the 90-ft. spans and 30-ft. bays between the concrete piers. The concrete surface appears to have been left just as it came from the wooden shuttering, and well suits the extreme simplicity of the building. Just as continuity of floor space was desirable on the ground level, unobstructed gangways for the travelling cranes were required at a higher point, and the level of the crane-rails has been accepted as the appropriate place to stop the concrete and commence the steelwork.

The economy of these straightforward arrangements is so obvious as to be, in some respects, beyond the reach of criticism, but it is possible to regret that no opportunity was found for any sort of centralisation or architectural emphasis which might have raised a respectable though purely utilitarian scheme to the dignity due to its scale and purpose. A central avenue of greater width than the rest would have given to visitors a means of identifying their position and of recognising the locality of such classes of exhibits as they particularly wished to inspect.

Some of the minor avenues in the

Palace of Industry have been provided with concrete trusses of an interesting form. The underside of each truss has been given the outline of a depressed four-centred pointed arch with its haunches fitted tangentially to the roof slope. Each truss is made in three parts, the two lower portions acting as brackets projecting from the walls or piers and the central part bridging the remainder of the span. It is not easy to say whether any steel has been inserted to connect the several slabs, and the S-shaped joints between them have opened slightly in some cases, either through irregularity in spacing the supports or through movements after erection. The movement is trifling, however, and the experiment well worth the making.

The few partition walls within the Palaces of Engineering and Industry that form part of their original structure, and are not parts of stalls erected by exhibitors, are made of concrete blocks without any special superficial treatment. The difference between the finish of the



British Empire Exhibition: Entrance to the Palace of Engineering.

blocks and that of the truss-slabs and piers is apparent, but not painfully so, and here again, though it is possible to recognise the appeal of absolute simplicity of construction, the contrast between the shells of the buildings and the highly finished and ornamented stands and the brilliantly coloured exhibits is destructive of anything approaching unity of effect.

In the Palace of Arts the design is carried through to a greater degree of finish, and concrete is again the material of construction. The front towards the lake consists of a central pedimented block containing the entrance doorway between square pilaster-piers with openings of smaller span to right and left of it. On each side of this central mass are wings which have the distinction of a slight batter, an extremely unusual refinement in a building prepared for exhibition purposes.

The walls of the wings are treated with vertical flutings and sunk horizontal bed joints, and contrast with the plinth and entablature which are left just as they came from the wooden mould. The pilasters are covered with slabs representing finely dressed masonry, though the plastic nature of the material is revealed by the marks left by the drip of cement from the shuttering for the lintel above. The differences in texture are a welcome contribution to the architecture, but even more vigorous treatment might have been given, for the grey colour of the concrete neutralises part of the value of the shadows in the joints and the fluting.

The soffit of the entrance portico is contrived with large flat beams and slabs which have square-edged sinkings of the simplest possible type, distantly reminiscent of classic coffering. The door and window openings in the walls are fitted with glazing in metal frames with their square panes subdivided diagonally in a manner that has become familiar to draughtsmen where time does not permit of elaborate pattern drawing and a classic effect has to be suggested.

In the interior the hesitation that too often characterises the British architect's handling of concrete appears in the thin edged opening leading to the Art Gallery in the centre of the building. After the massive piers of the portico and the entrance lobby the sudden descent to partition walls of extreme tenuity comes as something of a shock, and some sort of substantial frame to the edge of the opening is desirable to adjust the transition from the grand scale of the exterior to the smaller scale found suitable within. The interior is far more highly finished than were the Palaces of Engineering and Industry and the Art Gallery is conveniently proportioned with a large cove to the ceiling and a central lantern clerestory which illuminates the pictures on the walls more pleasantly than would have been possible with the system of top-lighting adopted in the two larger Palaces. The walls of the gallery are covered with canvas of a deep grey tone and the cove is tinted a light creamy buff, the effect being reposeful and charming.

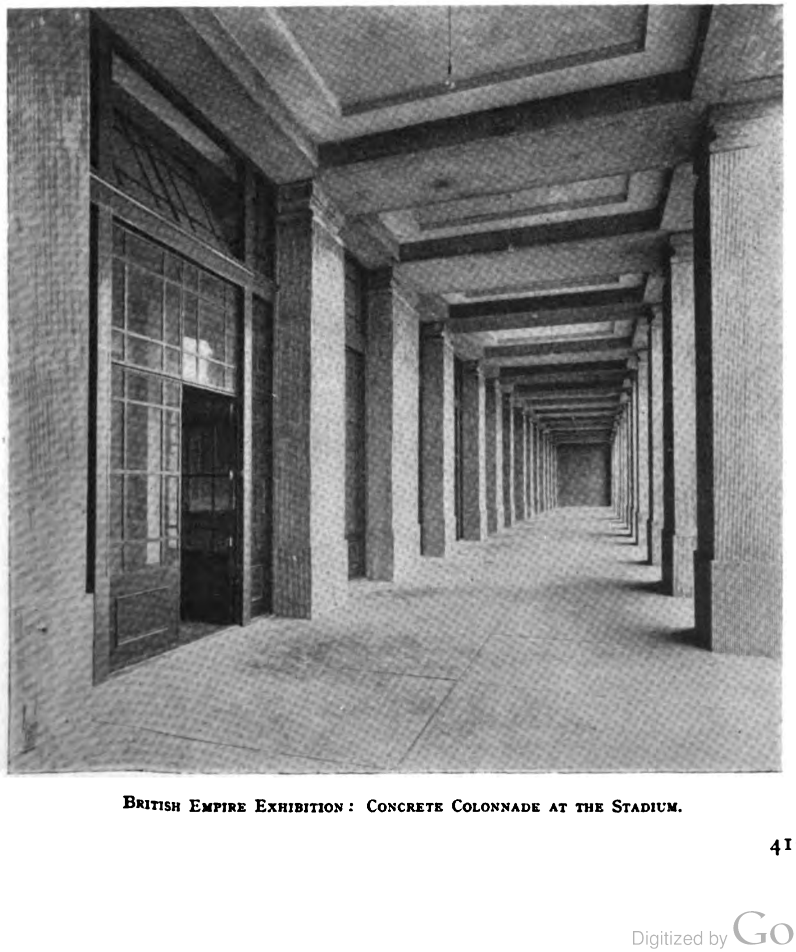
An interesting experiment in temporary concrete building is to be seen in the Basilica annex of the Palace of Arts where, though the interior is covered with colour decoration, the exterior shows that the walls which looked reasonably thick and substantial from within are but slender constructions of concrete blocks. The effect of depth in the window reveals is obtained by casting them in the forms of troughs whose bottoms are formed of stained glass. The whole trough has been given a rectangular margin and has been erected as a single unit. The stained glass is protected on the exterior by sheets of plate glass in metal casement frames hinged to open out for cleaning.

The Civic Hall building by the south entrance to the Exhibition is also concrete, built with three wide spans in front filled with glazed screens and glazed double doors and clerestory windows over. The interior comprises a large hall some 55 or 60 ft. wide with flat beam treatment and slabs forming the ceiling. The central panel is left open for light, though the actual skylight is hidden behind a ceiling cloth. One of the ceiling-beams in the outer hall exhibits a hair crack in the centre of the span, an unusual occurrence, for the buildings of all classes throughout the Exhibition seem to be standing exceptionally well in spite of the clay foundation which might have been expected to cause a lot of trouble.

Concrete used both decoratively and for convenience is exhibited in the great Stadium and in the towers and hall fronting it towards the Exhibition. The buildings include a variety of surface treatments, some parts having vertical flutings and sunk joints, others vertical flutings on the plain surface, while the high parapets show the marks of the uniformly narrow boards of which the shuttering was composed.

The design of the exterior has been divided into several distinct portions in order to permit of a more elaborate architectural style being adopted in the front, which stands opposite the central axis of the Exhibition. The massing of this central block is admirable and the long retaining wall to the platform in front of the building, which is pierced by a single round arched opening in the centre and flanked by two grand flights of steps, forms a splendidly solid base to the composition. The horizontal line of the terrace is repeated in the parapet of the flat-roofed building between the twin towers and in the main parapet at a higher level. The detail up to the top of the main parapet is simple and accords well with the large masses and the clever arrangement of planes. Above this the two towers commence to slope inwards, and the style and scale of the lower parts are somewhat lost. Instead of the building ending as it began in a composition of rectilinear masses, a series of minor breaks and steps reduce the square plan of each tower to an octagon which is still further diminished by mouldings upon the top of which is perched a little cupola seemingly far too small to crown the weight below. The battered walls to the angle pavilions of the towers and their small windows also seem to detract from the strength and scale of the building, and a monotonous equality in the spacing of the three lines of mouldings about the bases of the domes might have been avoided.

The smallness of these ornamental features becomes still more apparent



British Empire Exhibition: Concrete Colonnade at the Stadium.

when seen from an angle which brings the great arches of the side elevations into view and the changes in the architectural design would almost seem to indicate that three different buildings had been erected. The variations of spacing in the rectangular piers of the hall facing the terrace and the different sizes of the piers themselves give even this front a rather puzzling air of unaccountable irregularity until it is recognised that the openings are arranged in five groups of three with broader spans in the centres of the five bays. Inspected more closely, the concrete facings of the sides of the Stadium are seen to be comparatively thin and have been erected with vertical joints at the crowns of the great arches. The seating, constructed on concrete steps built up to form a great oblong amphitheatre is, however, principally supported upon steel lattice stanchions and girders, and is not altogether dependent upon the strength of the facings.

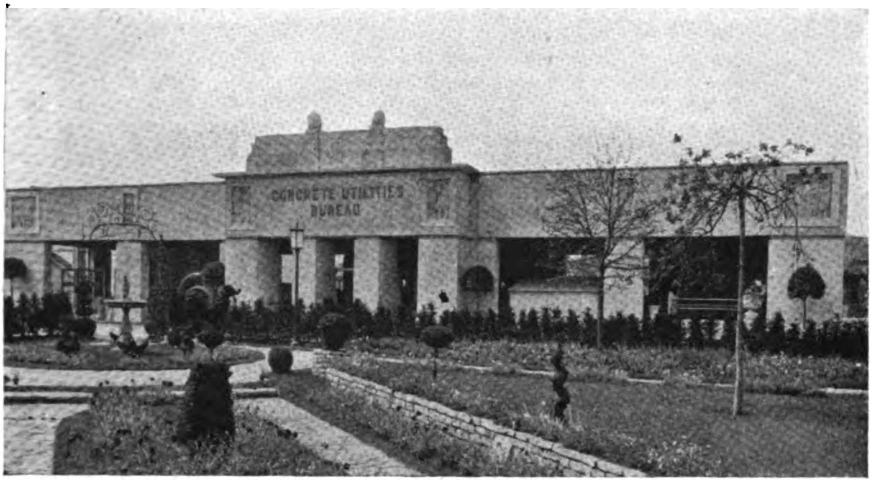
The adaptability of concrete for practical purposes is well illustrated in the stairways, where the hanging strings are made, in some cases, to the crooked line of flight and landing between one support and the next. The projecting concrete-walled staircases with their unglazed mullioned windows introduce yet another diversity in the architectural scheme, but are extremely interesting as examples of utilitarian construction of a somewhat experimental character. Additional floor space has been obtained at their tops by boldly corbelling out at the roof level.

In H.M. Government building the tenacious character of concrete is well expressed in the broad spans in the interior. The exterior follows the same general type as the Palace of Arts, with strong square pilaster piers to the central entrance and plain massive-looking wing walls built, in this case, of concrete blocks.

The principal entrance is raised on a fine flight of external steps decorated with colossal statues of couchant lions, which have been modelled with dignity and are cast in concrete. The play of light on their rounded surfaces relieves the severity of the fine pile, but seems to call for a mass of sculpture in the deep frieze above to carry the same quality throughout the façade.

The interior of this hall is a lesson in the advantages to be derived from adapting design to suit the character of the material of construction. The wide intercolumniations made possible by the use of reinforced concrete have been successfully composed, and the concrete beams and parapets are all well thought out. The open well staircases with concrete steps and landings have been provided with solid parapets instead of hand-rails, and are particularly good and suggestive pieces of work. Interest is increased by allowing the edges of the steps to appear in the well. Fluted surfaces have been made use of in several places and colour decoration of a simple and effective sort has been applied to the ceiling beams. Even the standards which support the rails guarding the empire map have been made of concrete with fluted surfaces.

In the bridges across the lake the massive style of these buildings has been abandoned, and the work is carried to the opposite extreme of lightness. The thin edge of the concrete bridge deck projects on each side beyond the planes of the arched slabs of concrete which support it and cuts off by its shadow the crown of the arch, which is reduced almost to nothing in any case. The bridges are provided with iron handrails though concrete parapets would have added a much-needed feeling of solidity and security to the frail-looking structures. Fluting the surfaces has been adopted but hardly suffices to give interest to arches which appear weak. Suggestions for the improvement of design in concrete may be gleaned from many of the temporary buildings, and interesting comparisons made to its advantage by observing the state of the fibrous plaster work in the Exhibition. This has already begun to show signs of wear, and also a tendency to shed its coat of colour decoration. How much more might have been done in the way of permanent colour and surface treatment for the various buildings is illustrated in the pavilion of the Concrete Utilities Bureau, which embodies a spirited effort towards exhibiting the possibilities of concrete architecture. This pavilion designed by Mr. Clough Williams-Ellis is composed of simple massive piers with a high flat parapet, all projections and sinkings of the surface being kept consistently slight in sympathy with the character of the material. Panels of sculpture by Mr. Gilbert Bayes are also arranged in flat planes in low relief and give a great deal



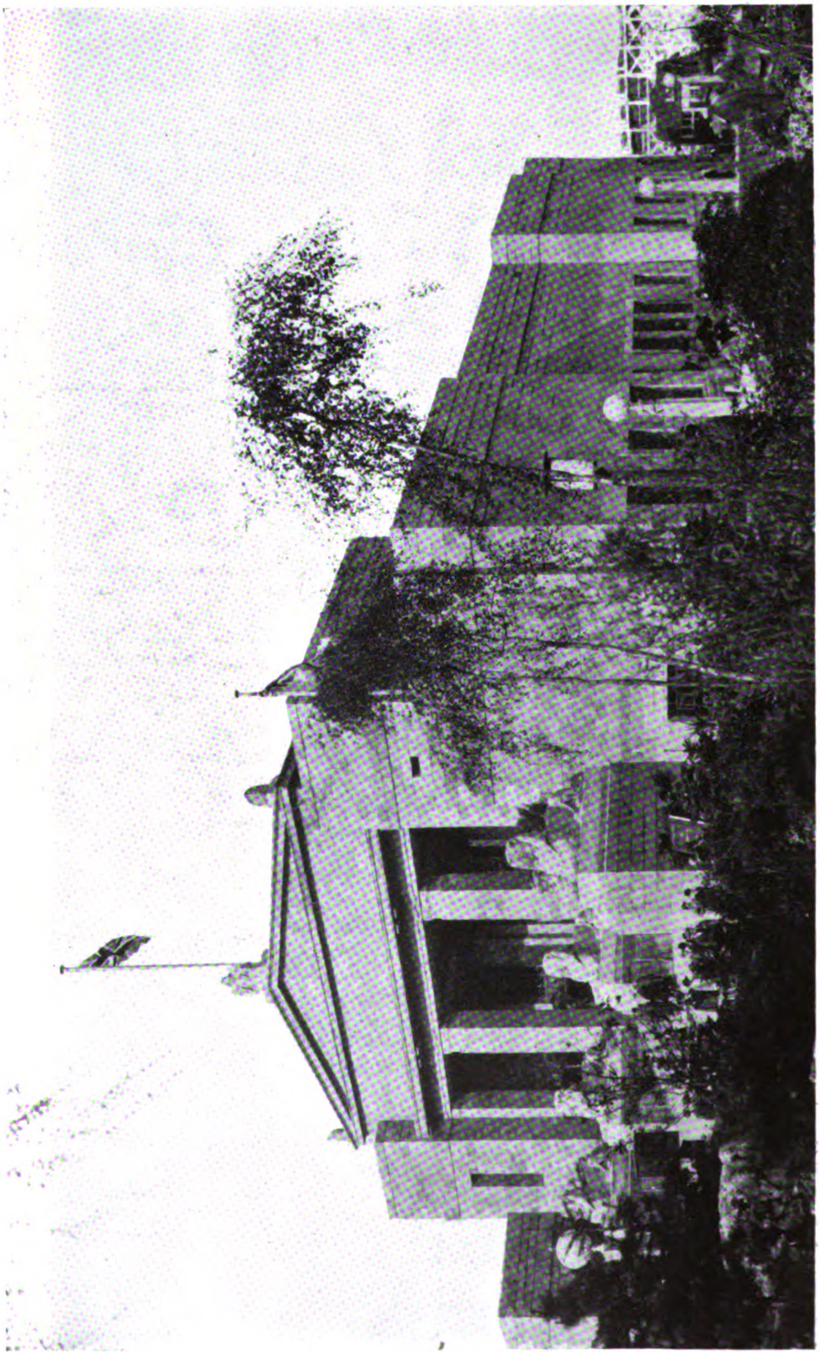
British Empire Exhibition : The Stand of the Concrete Utilities Bureau, showing Cement Plaques by Mr. Gilbert Bayes.

of interest to the building. A little colour has been introduced by some blue bands under the coping and at the bearings of the lintels, but although the hue is distinctly pleasant and rich there is not quite enough of it, nor is it sufficiently woven into the design to make a colour scheme. Means have been found to make the pigment adhere to the concrete, however, a point in which it contrasts favourably with the peeling paint on several of the stucco-fronted temporary buildings.

Even more interesting is the collection of panels in the interior of the building, which illustrate the many different manners in which permanent surface treatment may be applied to concrete. Some of these methods have been familiar for centuries, others, equally suitable, are quite new, but are obviously as sound as they are beautiful. A series of fine panels with a pebble finish in black and white, red and blue, is exhibited, and a great deal is to be hoped for if these interesting experiments are continued and applied to building with understanding. Examples of concrete with the surfaces tooled to resemble stone will appeal to those who wish to achieve a masonry structure at a sensible reduction of cost, and though the appeal of concrete does not stand or fall merely on the question of successful imitation, the work is thoroughly well done. Pergolas, garden furniture, bird baths and sundials are among the ornamental objects, and utilities such as concrete fences, pipes and manholes are also shown. A road surface of reinforced concrete and an elevated portable stand for a corn stack that can easily be carted and erected without the use of cementing material are also among the exhibits.

Throughout the Exhibition concrete has been used for pavings, platforms, trestles and elevated railway tracks, and if the constructional engineer has rather outpaced the architect in its appreciation and employment, signs are not wanting at Wembley that the future will see a more consistent development of beauty of presentation in this material. A great deal has been achieved in this direction and any faults that may be found may fairly be put down to the difficulties of the case. They are all of a nature to be remedied, and the remedy is often suggested by other exhibits. Concrete design can be made more appropriate by taking a hint from the flat-walled continuous-surfaced buildings of the East, and such buildings are to be seen in the Exhibition. Colour and surface treatment may also be improved, and the way of improvement is clearly laid down by some of the exhibits just described.

The architects for the Exhibition are Messrs. Simpson & Ayrton, FF.R.I.B.A., and Sir E. Owen Williams is the engineer. Some notes on the construction of the Exhibition buildings, by Sir E. O. Williams, are given on p. 421.



BRITISH EMPIRE EXHIBITION : H.M. GOVERNMENT BUILDING.

THE CONSTRUCTION OF THE BRITISH EMPIRE EXHIBITION.*

By Sir E. OWEN WILLIAMS, K.B.E., B.Sc., A.M.Inst.C.E.,
Engineer to the Exhibition.

THE ideal structure is one in which the materials fit the conditions better than any other materials, and in which the form, both architectural and engineering, fits the material. It has been my endeavour as a guiding principle to use no material where another material would better serve. To have used concrete where concrete should not be used would, apart from bad engineering, be of no service to the material itself, and remembering this it is to the credit of this material that without any fetish for its use it has provided the solution for the greater number of the constructional problems at Wembley.

By the suitability of material is meant the degree of satisfaction of

(1) Architectural requirements, because an exhibition must be beautiful.
(2) Speedy construction, because it is the essence of an exhibition that it should be finished by a specified date.
(3) Reliability, because the conditions of the building of an exhibition prevent meticulous inspection and require the utilisation of whatever labour is available.
(4) Economy, because an exhibition is even more than usually underfunded.

The Exhibition buildings were entirely completed on the opening day, which is unusual in exhibitions; reliability is proved by the fact that 200,000 tons of concrete have been placed, the greater part within one year, without a single failure; and, last, but all-important, the comparison of the cost of the permanent buildings of the Palaces of Engineering and Industry with exhibition buildings of the past is a striking testimony to the material. During a period when the cost of building operations had doubled, the cost of the permanent buildings of the Exhibition was only 25 per cent. more per sq. ft. of floor area than the exhibition buildings of the White City.

In the construction of the Exhibition there was used about 125,000 yards of concrete, requiring 35,000 tons of cement. A large proportion of this was in mass. Mass concrete was used throughout the Exhibition for foundations. The subsoil at Wembley is entirely clay, which demands that the foundation bottoms should be covered up immediately they are exposed. This is better done with mass concrete, as it avoids the delay caused by the placing of steel reinforcement, and is certainly not more expensive if all factors are considered. It was even found expedient to have all reinforced concrete retaining walls on mass concrete bases.

The mass concrete proportions were 8 to 1 and 6 to 1, depending upon whether the work was in the ground or had exposed surfaces.

The size of aggregate permitted was as large as was reasonable for the minimum dimensions of mass concrete used, which was 1 ft. in thickness. It is necessary to impress the importance of the use of the largest possible size of aggregate compatible with the thickness of the mass concrete. There is a danger of this being overlooked, because reinforced concrete for other reasons has been specified to have ¾-in. aggregate, or even less, and this has encouraged a fallacy that good quality concrete must necessarily be made from small size aggregate. To break up stones for the purpose of subsequently sticking the parts together again with cement is a patent absurdity; the cement is far better employed in making a better mortar binding the larger stones together.

The mass concrete specification does not call for separation and then mixing of large and fine aggregates. The stresses in mass concrete are never high, and, provided limits are fixed to the quantity of material below ¼-in. mesh in the ballast, sufficiently good quality mass concrete is obtained at minimum cost. Sufficient material below ¼-in. mesh must be in the mixture to fill the voids between the large stones, but not so much as to eat up the cement, and this is the reason for fixing in the specification the superior and inferior limits.

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* Abstract of a paper read at the Annual Meeting of the Institution of Municipal and County Engineers.

The tests on the concrete cubes made in accordance with the specification showed consistently good results. For 6 to 1 concrete a cube test result at twenty-eight days of 1,400 lbs. per sq. in. can be relied upon. For 8 to 1 concrete 900 lbs. per sq. in. was a reliable cube test. Working stresses of 18 tons and 12 tons per sq. ft. respectively gave factors of safety of 5.

For the same reasons which in mass concrete demand that as large aggregate as possible should be used, so must sand be as large and free from fine material as is consistent with density. The specification rigidly fixes limits of percentages passing through various size sieves. It will be found that any good-class sand for reinforced concrete will satisfy this specification, and that the specification is not as onerous as it may appear, although it provides a criterion which immediately rejects the finer sands which, unfortunately, are often submitted.

It is too often forgotten that concrete consists not only of coarse aggregate, fine aggregate, and cement, but also water. Water is the most significant partner in the combination of the four materials. It has been established that 10 per cent. too much water effects a 20 per cent. reduction of strength in a 4 : 2 : 1 mixture, whilst 10 per cent. too little cement effects only 10 per cent. reduction in strength; and from these figures it is seen that in a rough and ready way the water proportion is twice as important as the cement proportion. Great care is often exercised in checking the percentage of cement, whilst little regard is paid to the percentage of water. In fact, there are specifications in existence which actually ask for a sloppy mixture. There is no property of concrete which is not injured by an excess of water. Varying results of the test cubes, poor wearing properties, dustiness, and weak bond strength are largely attributable to lack of care in gauging the water.

The effect of the water is to bulk the concrete, creating a filament between the aggregate and mortar, and this bulkage is at once detectable by the weight of the concrete test cubes. Relative weights of 6-in. concrete cubes made of the same materials give a good criterion of the amount of water which has been used in mixing, and afford a means of anticipating the crushing tests, i.e. the light cube gives a poor result as compared with a heavy cube. There is admittedly a difficulty in strictly specifying the percentage of water because of the varying percentage of moisture in the aggregates. The correct percentage of water for workability and strength of reinforced concrete is for all mixes 5 per cent. of the weight of sand and stone, plus 30 per cent. of the weight of cement. The sand and stone usually contain 2½ per cent. by weight of moisture, and, indeed, if the sand and stone are drier than this they should be moistened before being put into the mixer. Allowing for this percentage of moisture, the weight of water required will be 2½ per cent. of the weight of stone and aggregate plus 30 per cent. by weight of cement, and this is the basis of the water proportions given in the specification.

The reinforced concrete construction commenced generally above ground level, and the development of reinforced concrete from mass concrete was accompanied by an increase in the percentage of cement.

Mass concrete is essentially a material depending upon its weight for its stability. Stresses are necessarily comparatively low; and only sufficient cement need be used to bind the aggregate and prevent its returning to its original natural state. The sizes, such as thickness of a mass concrete retaining wall, are determined entirely by the weight of the concrete, i.e. a higher quality concrete would not permit of reduced thickness. The quantity of mass concrete makes the percentage of cement a considerable factor in the cost of the work, and this caused engineers to reduce the percentage of cement to the minimum.

Reinforced concrete, on the other hand, does not depend for its stability on its weight, and in some cases, such as long span bridges, its weight is a distinct handicap. The stability of reinforced concrete rests fundamentally on its compressive strength and its bond or adhesion to the reinforcing steel.

It is an interesting experimental fact that the strength of concrete varies directly with the percentage of cement in the finished concrete. A 4 : 2 : 1 mixture contains 510 lbs. cement per yard cube of finished concrete; a 3 : 1½ : 1

mixture contains 640 lbs.; and a 2 : 1 : 1 mixture contains 860 lbs.

The allowable working stresses are in the same proportion, i.e. if 510 lbs. per sq. in. were fixed as an allowable working stress for 4 : 2 : 1 concrete, so 640 lbs. and 860 lbs. would be the allowable stresses for 3 : 1½ : 1 and 2 : 1 : 1 respectively. It follows from this that a ton of cement, whether in a column 1 ft. sq. section or in a column of weaker concrete 2 ft. sq. section, would support exactly the same load; and then it must follow that high quality concrete with high percentage of cement is a direct economy, as no more cement is used, but considerably less aggregates and moulds. There is a still more important result, and that is that the bond or adhesion between concrete and reinforcement also varies directly as the tonnage of cement in a yard of concrete, and as the structure depends ultimately upon the bond on the two materials, concrete and steel, the concentration of the cement into a smaller mass directly results in increased security.

Speaking broadly, 4 : 2 : 1 concrete cannot be considered water-tight; 3 : 1½ : 1 will be with good workmanship; and 2 : 1 : 1 certainly will be unless the workmanship is alarming. The life of the structure must depend upon its impermeability, again favouring the high quality mixture.

It may be asked, where should this increase in the mixture cease? There is a practical limit to the reduction of sizes of concrete members consistent with properly surrounding the reinforcement, and when these practical limits have been reached the percentage of cement in the concrete need only be sufficient to provide a concrete capable of withstanding the resultant stresses. For normal structures 3 : 1½ : 1 mix provides for this, and has been used throughout the Exhibition.

For marine works and structures where the weight of the structure is the predominant feature in the design, such as long-span bridges, 2 : 1 : 1 concrete, or even richer, should be used. A further advantage of the richer mixture is its greater workability, as the cement is a lubricant. This tends to correct the tendency with weaker mixtures to increase the percentage of water to make the concrete run into the moulds.

There has been argued against the use of rich mixtures the possibility of danger from increased shrinkage during setting, but during the last six years I have used up to 2 : 1 : 1 mixtures in structures of considerable length without any trouble from this cause. The use of rich mixtures induces a change of attitude towards concrete. It has been said that the difference between the rich mix and a poor mix is not a difference of degree, but provides a different material eliminating the feeling of uncertainty with which concrete is sometimes regarded.

The history of reinforced concrete has been one of slow acceptance by engineers. It has passed the Cinderella period; but what of its use architecturally? Architecturally it has largely been regarded as a somewhat mysterious alternative, only to be adopted for economy, or put in to support a façade of other material in which it is hastily clothed to hide its nakedness. The buildings of the Exhibition witness a new architectural stage in the history of reinforced concrete. It is entering upon an era possibly of slow acceptance to architects, but ultimately must develop an architecture of its own, in the same way as it has developed a branch of engineering.

When regarded purely as an engineering subterfuge to be clothed by the architect in more seemly material, intimate co-operation between architect and engineer was, if absent, not disastrous. When the material is to be used both architecturally and structurally the co-operation of the architect and engineer is essential. Architecturally concrete has not yet developed, and temporarily there must be a gap between its architectural and engineering form, but as the material and its technique are more studied by both professions so will its accepted architectural and engineering proportions more and more coincide.

Whilst concrete served so well the purposes of the Exhibition, yet the Exhibition has served an equally useful purpose for concrete. Here it has achieved a publicity which must surely eradicate any faint-hearted uncertainty and establish it as an accepted material.

There are scattered all over the country fine examples of reinforced concrete construction, but here are collected together examples of every conceivable use of the material on which twenty or

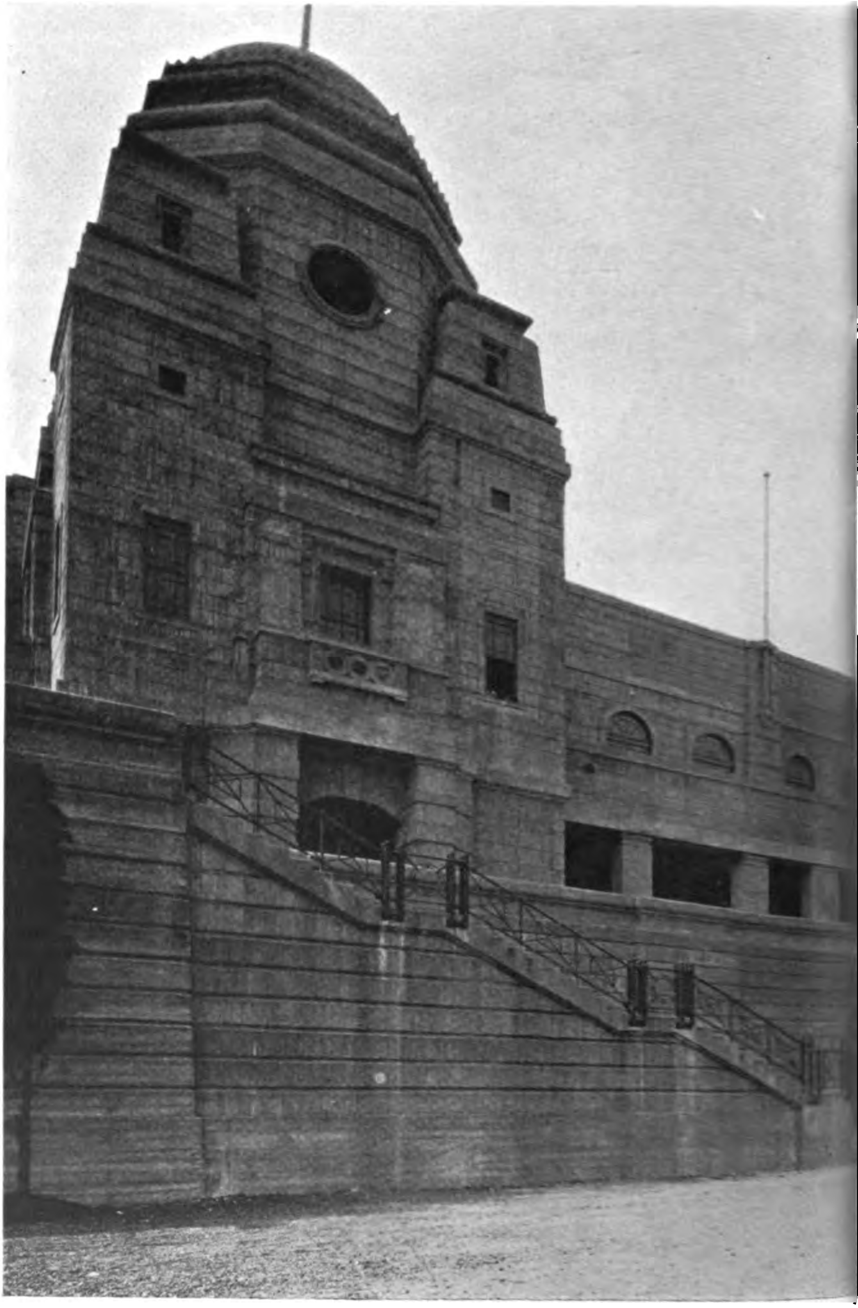
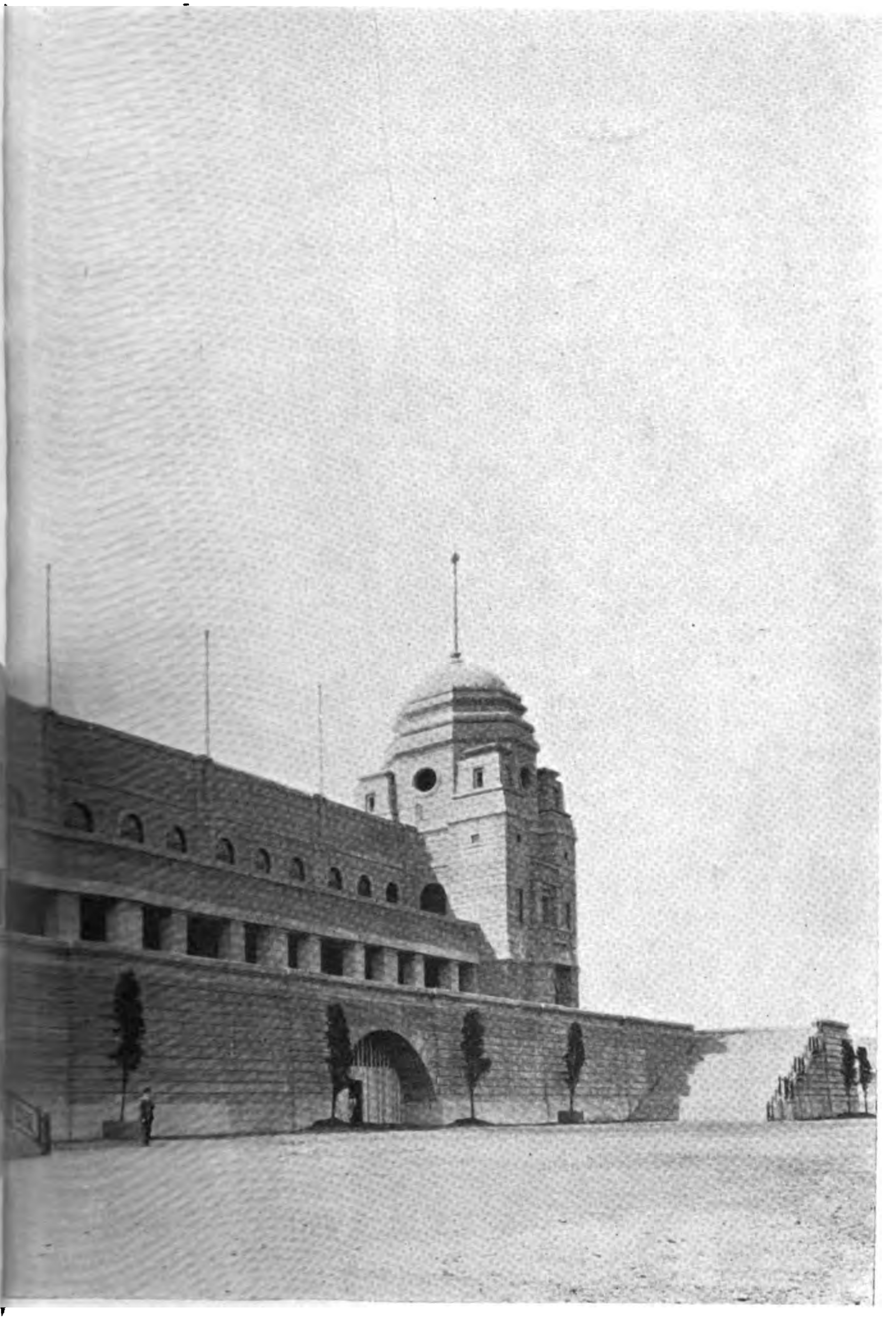


Photo: Campbell Gray.]

BRITISH EMPIRE EX



[*Messrs. Simpson & Ayrton, FF.R.I.B.A., Architects ; Sir E. Owen Williams, A.M.Inst.C.E., Engineer*

TION : THE STADIUM.

more millions of the public will gaze. This variety must impress upon the public the adaptability and stability of concrete, and bring home the epoch-making invention of the Englishman who one hundred years ago invented Portland cement, an invention as fundamental as the invention of bricks.

SPECIFICATIONS.

MASS CONCRETE.

The following specifications used for the concrete work at the Exhibition were given by the author in his paper :

Cement.—See clause in specification for reinforced concrete.

Ballast.—This shall be of clean, hard stone, gravel, or approved broken brick. Unless otherwise specified the maximum diameter shall not exceed 3 in. The material shall be well graded, and not less than 25 per cent. nor more than 35 per cent. shall pass through ¼-in. square sieve. Material which is otherwise suitable but does not conform with these limits on the ¼-in. sieve may be improved by the addition of large material or clean, coarse sand to make it then come within these limits.

Proportions.—The working drawings will specify the proportions in parts of ballast to parts of cement. The proper proportion of ballast is to be measured by volume in gauge boxes, but the proportion of cement by weight, it being understood that 1 cubic foot of cement weighs 90 lbs.

Water.—Only clean fresh water is to be used for mixing the concrete. The quantity of water used is to be a minimum consistent with properly placing the concrete.

Mixing.—An approved machine mixer is to be used unless the quantity of concrete is very small, when hand mixing will be permitted if by a method approved by the consulting engineer. The mixing platform is to be suitably protected from wind to prevent the finer particles of the cement being blown away.

Concrete Tests.—Every first and third week of every month, and when directed by the consulting engineer, the contractor shall make four 6-in. cubes in steel moulds, under conditions exactly similar to those of the actual work, of each class of mass concrete being used. The contractor shall send the cubes to a testing laboratory selected by the consulting engineer, where three cubes of each set will be tested at the contractor's expense when twenty-eight days old and the remaining one when ninety days old. The contractor shall place an identification mark on each cube, and keep a record of date of casting and proportions, and shall notify such information to the testing laboratory when sending cubes for testing.

Placing Concrete.—Before placing concrete all moulds and centering are to be cleaned of all sawdust, wood, or dirt, and thoroughly watered. All concrete shall be placed as soon as possible after mixing, and shall not be used if a period of more than half an hour elapses after mixing. Concrete which has been in position for more than half an hour shall not be disturbed, jarred, or vibrated until it has set.

Weather Conditions.—No concreting is to be carried on when the thermometer is below 36 degrees Fahr. on a falling thermometer or below 34 degrees Fahr. on a rising thermometer, except when precautions approved by the consulting engineer are adopted. The exposed surfaces of green concrete must during frosty weather be suitably protected. During hot weather, especially when accompanied by a high wind, freshly placed concrete must be kept thoroughly watered and protected by sacking or otherwise until well set.

Records.—The following records of concreting are to be kept by the contractor during the progress of the work for the information of the consulting engineer :—

(1) Maximum and minimum temperature throughout day from noon to noon.

(2) State of atmosphere, whether
  (*a*) Dry, medium, or moist.
  (*b*) Gale, windy, or calm.
  (*c*) Sunshine or cloudy.

(3) Position of portion of structure concreted each day to be clearly marked on a set of drawings and preserved for reference.

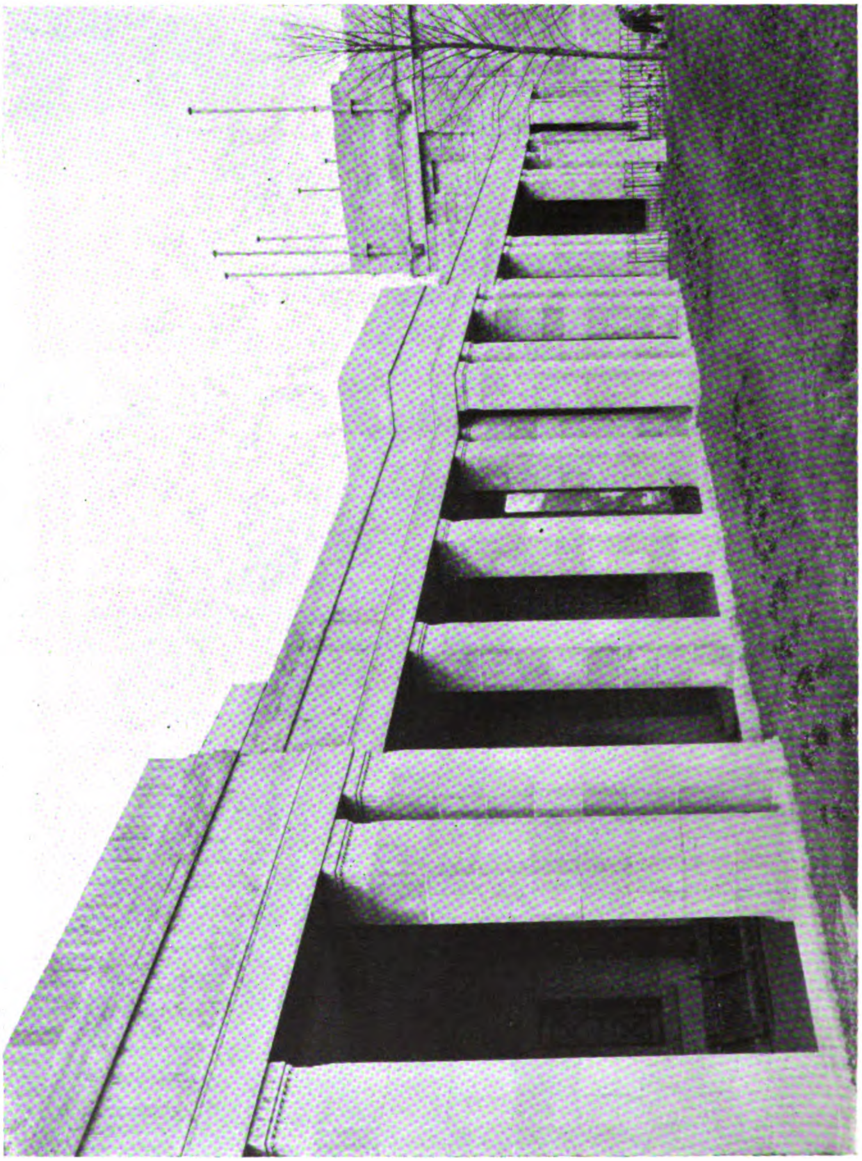
REINFORCED CONCRETE.

Cement.—The cement shall be British Portland from a works approved by the engineer, and shall at least comply with the latest British Standard Specification for medium or slow-setting cement, except that the residue on the 180 sieve shall not be more than 10 per cent. The procedure for testing cement shall be as follows, and at the expense of the contractors. Whenever a consignment of cement is ready at an approved works for delivery the contractor shall immediately notify a chemist selected by the engineer. The chemist will sample the cement at the makers' works and seal the bins. He shall test in accordance with the British Standard Specification and report the results to the engineer. On receiving the approval of the seven-day test by the engineer the chemist will unseal the bins and witness the bagging and despatch of the cement. Should the twenty-eight-day test show failure to comply with the specification, the use of the cement of that consignment is to be discontinued and removed from the site within three days of notification by the engineer to the contractor. No cement untested in accordance with this procedure, or having failed under this test, shall be brought on to the site. Stored cement is to be protected from moisture in an approved weather-tight shed. No sacks shall be placed directly on the ground. The storage is to be so arranged that the cement consignments are used in the rotation in which they arrive. Each consignment is to be kept separate and distinguished. If any cement is stored on the works for a period exceeding two months the engineer may direct the contractor, at his expense, to notify the selected chemist to re-test. If such re-test is unsatisfactory, or if in the opinion of the engineer the cement has been injured by storage, the remainder of the consignment shall be removed from the site by the contractor within three days of being notified by the engineer.

Coarse and Fine Aggregate.—Generally, both fine and coarse aggregates will be accepted if they give the test results hereinafter specified for compression, provided they are not, in the opinion of the consulting engineer, otherwise defective or contaminated. A set of six nesting sieves, 10 in. diameter, with cover and tray, 1½-in. sq. mesh, ¾-in. sq. mesh, 1-in. sq. mesh, No. 10, No. 30 and No. 50, shall be provided by the contractor and kept on the works.

Fine Aggregate.—This shall be clean, hard and coarse, and free from any trace of tannic acid. Pit sand must be washed, unless otherwise allowed in writing by the consulting engineer, and other sands or fine material shall be washed if considered desirable by him. No more than 30 per cent. shall pass through a standard No. 50 sieve, not more than 60 per cent. nor less than 25 per cent. shall pass through No. 30 sieve, not more than 85 per cent. nor

ONE OF THE BRIDGES OVER THE LAKE AT THE BRITISH EMPIRE EXHIBITION.



BRITISH EMPIRE EXHIBITION: THE COLONNADE NEAR LLOYDS BANK.

less than 70 per cent. shall pass through No. 10 sieve, and not less than 95 per cent. shall pass through ¼-in. sq. mesh sieve.

Coarse Aggregate.—This shall be of clean hard stone, gravel, or approved broken brick of cubical or spherical shape. Pit gravel shall be washed unless otherwise allowed by the consulting engineer, and other aggregates shall be washed if considered desirable by him. Where specified as ¾-in. aggregate it shall vary in size between ¾-in. and ¼-in. maximum and minimum dimensions. Where specified as 1½-in. aggregate it shall vary in size between 1½-in. and ¼-in. maximum and minimum dimensions.

Reinforcing Steel.—Reinforcing steel shall comply with the latest British Standard Specification for mild steel for bridges and general building construction. The contractor shall provide reasonable proof of the quality of the steel, but when directed by the consulting engineer the contractor shall submit, carriage paid to an approved testing laboratory, test pieces selected by the consulting engineer. In the event of steel being rejected, the consignment covered by the rejection shall be removed from the works within seven days by and at the expense of the contractor. All steel shall be free from oil, dirt, or scale, but a slight film of rust will not be objectionable. Welding will not be permitted unless agreed in writing by the consulting engineer.

Water.—Only clean, fresh water to be used for mixing concrete or grout.

Proportions.—The proportions by volume of the concrete for the various parts of the structure are specified on the working drawings. The proper proportions of sand and stone are to be determined by volume by accurately-made gauge boxes, to be provided by the contractor, but the proportion of cement is to be determined by weight, it being understood that 1 cubic foot of cement weighs 90 lbs. Great care is to be exercised in the gauging of the water used in mixing, as it is essential that the concrete be not sloppy. The water supply to the mixer is to be adjusted until the resultant concrete flows sluggishly out of the mixer.

Table A gives an idea of the correct quantity of water to be used, but the exact amount depends on the brand of cement and the class and size of stone and sand. When concreting is recommenced after a delay exceeding one hour, the first two mixings are to have 10 per cent. excess of cement beyond what is demanded by the quantities or drawings.

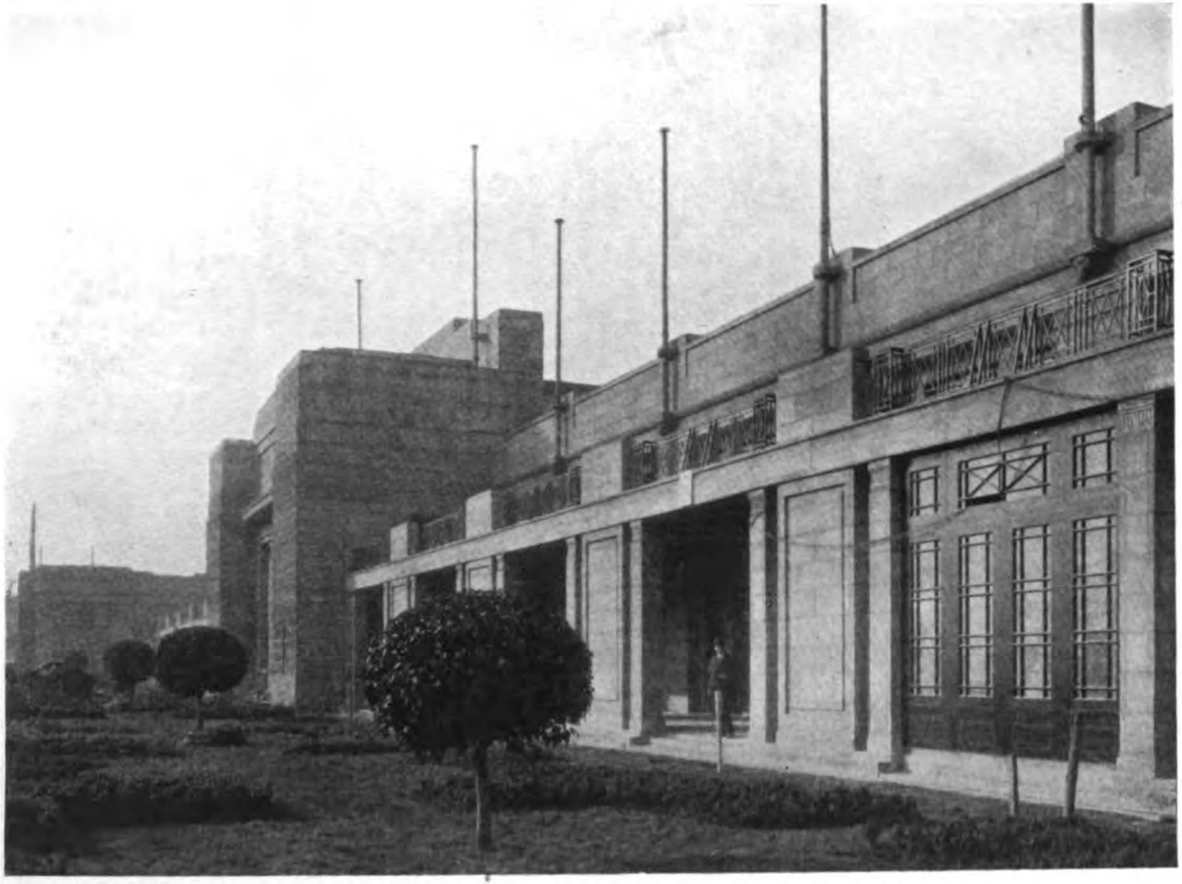
TABLE A

Proportions of Concrete Materials	Quantities of Materials required per bag of Cement			Water in gallons required per bag of Cement, but to be modified by trial
	Coarse Aggregate cu. ft.	Fine Aggregate cu. ft.	Cement lbs.	If Sand and Stone moist
3 1½ 1	6¾	3⅜	204	8¼ gallons
2 1 1	4½	2¼	204	7½ gallons

Mixing.—An approved machine mixer is to be used unless the quantity of concrete required is very small, when hand mixing will be permitted if by a method approved by the consulting engineer. When mixing ceases the mixer is to be thoroughly washed out, and when recommencing the mixer is to be again washed out with cement grout. The contractor is to provide and maintain a proper mixing platform, suitably protected from wind to prevent the finer particles of the cement being blown away.

Concrete Tests.—On receiving any new consignments of cement or fine aggregate or coarse aggregate, and every first and third week of every month, and when directed by the consulting engineer, the contractor shall make, under conditions exactly similar to those of the actual work, four 6-in. cubes in steel moulds provided by the contractor. The contractor shall send the cubes carriage paid to a testing laboratory selected by the consulting engineer, where three cubes of each set will be tested when twenty-eight days old and the remaining one when ninety days old. The contractor shall place an identification mark on each cube and keep a record of date of casting and proportions, and shall notify such information to the testing laboratory when sending cubes for testing.

The average results of each set of cubes should not be less than given in Table B for the different mixtures. If concrete has been used in the structure, and the tests of which have proved deficient according to Table B, such concrete shall



BRITISH EMPIRE EXHIBITION: THE PALACE OF INDUSTRY.

not be fully loaded for a period fixed by the consulting engineer, and to prevent a recurrence of defective tests either a slight addition to the percentage of cement shall be made or other materials to be used at the option of the consulting engineer, but at the contractor's expense.

TABLE B

Proportions by volume	Average ultimate compressive strength of 6-in. cube in lbs. per sq. in.	
	28 days old	90 days old
3 1½ 1	2,100	3,100
2 1 1	2,700	4,000

Placing Concrete.—Before placing concrete all moulds and centering are to be cleaned of all sawdust, wood, or dirt, and thoroughly watered. All concrete shall be placed as soon as possible after mixing, and shall not be used if a period of more than half an hour elapses after mixing. The concrete is to be thoroughly puddled into the forms, care being taken to surround all reinforcement. Concrete which has been in position for more than half an hour shall not be disturbed, jarred, or vibrated until it has set. The upper surface of flat work shall be levelled off with a wood screed unless otherwise specified. Immediately after the removal of centering or moulds any holes or cavities in the exposed surface of the concrete are to be filled with cement mortar and left with a neat and workmanlike appearance. If plastering is specified the concrete surface is to be roughened to form a key for the plaster or other finish.

Weather Conditions.—No concreting is to be carried on when the thermometer is below 36 degrees Fahr. on a falling thermometer or below 34 degrees Fahr. on a rising thermometer, except when precautions approved by the consulting engineer are adopted. The exposed surfaces of green concrete must during frosty weather be suitably protected. During hot weather, especially when accompanied by a high wind, all freshly placed concrete must be kept thoroughly watered and protected by sacking or otherwise until well set.

Joints other than those in Pre-cast Construction.—Joints, when necessary, are to be clean vertical or horizontal joints, and those in beams and slabs are preferable at the centres of spans. Joints between two days' working are to be kept moist, and before recommencing concreting are to be given a slight coating of stiff cement mortar. The new concrete is to be of a slightly drier consistency than usual and well rammed against the older concrete. Long-standing joints are to have all dust and foreign matter removed with a dry wire brush, then moistened and treated as given above for a two-day joint.

Records.—The following records of concreting are to be kept by and at the expense of the contractor during the progress of the work for the information of the consulting engineer :—

(1) Maximum and minimum temperature throughout day from noon to noon.
(2) State of atmosphere, whether
  (*a*) Dry, medium, or moist.
  (*b*) Gale, windy, or calm.
  (*c*) Sunshine or cloudy.
(3) Position of portion of structure concreted each day to be clearly marked on a set of drawings and preserved for reference.
(4) Gallons of water used per batch with particulars of quantities of materials used per batch. (It will only be necessary to note any change in the amount of water and proportions.) Any exceptional dryness or wetness of stone or sand is to be recorded, especially when test cubes are being cast.

Bending Reinforcement.—The reinforcing steel shall be accurately bent to the shapes shown on the detail working drawings supplied by the consulting engineer. When not otherwise specified on the working drawings, all bends are to be to easy radii.

Placing Reinforcement.—After being bent, the steel reinforcement is to be placed and supported in the moulds in the positions shown on the detail working drawings.

Dimensions.—All reinforcing steel shall be of the exact diameters shown on the detail working drawings. Dimensions of concrete given on the detail working drawings are to be considered minimum sizes.

Centering.—Except when exposed surfaces are specified to be plastered, all timber used for centering shall be wrot. All centering must be erected true to line and level, sufficiently rigid, and braced to carry the weight of the wet concrete without appreciable deflection or vibration. All joints in centering must be reasonably tight to prevent the escape of liquid cement. The bottoms of all beam boxes shall be given a camber of ¼ in. per 20 ft. of span. Centering before re-use is to be thoroughly cleaned.

Striking Centering.—The centering is to be designed so that its removal can follow the rotation (1) beam sides, (2) slab centering, (3) beam bottoms and supporting props. The removal of centering is to be done with great caution and care, and is the contractor's responsibility. The periods stated in Table C are a minimum, and based on the assumption that weather conditions are normal and that the work is not loaded in any way. If frost has occurred, extra time must be allowed for the concrete to set sufficiently.

TABLE C

Part of Structure	Minimum period after casting before striking centering. Normal conditions and no loading assumed
Vertical wall centering	3 days.
Column boxes	3 days.
Beam sides	3 days.
Flat slab centering up to 6 ft. span	6 days plus 1 day for every additional 1 ft. of span.
Beam bottoms and props	21 days

PRE-CAST CONSTRUCTION.

Generally.—The whole of the foregoing clauses, unless expressly excepted, shall apply to pre-cast construction. It is of great importance that the dimensions of pre-cast beams and slabs as given on the detail working drawings be exactly adhered to, and the projection of steel reinforcement from the beams and slabs be in strict accordance with the detail drawings and sketches.

Removal of Moulds.—Moulds to sides of beams and edges of slabs may be removed in not less than two days, provided it is not necessary to move such beams or slabs to effect this operation.

Moving Beams and Slabs.—Pre-cast beams and slabs shall not be moved from the positions in which they were cast for at least ten days or such longer period as may be considered advisable by the contractor.

Erection of Beams and Slabs.—Pre-cast beams and slabs shall not be erected until they are fourteen days old, or such longer period as may be considered advisable after inspection of the members. Where one concrete member bears on another concrete member the bearing surface is to be thickly coated with a two-to-one sand and cement mortar immediately before the concrete member is placed on the bearing. All beams and slabs are to be placed in the correct positions and levels as shown in the detail working drawings, with the steel reinforcement interlocking as required.

Striking Temporary Timber Bearers.—Timber bearers temporarily supporting the slabs are not to be removed in less than seven days after the slab joint has been cast. When the slab is cast in position on pre-cast beams the period for removal of its centering is to be the same as for *in situ* slabs, as before specified.

Joints.—Before any joints are cast they must be finally examined to ensure that all the steel reinforcements specified are in position. The joint must then be cleaned of all dust and other foreign matter, and scoured with water so as to moisten thoroughly the adjacent concrete, immediately before concreting the joint. The concrete in joints between pre-cast beams and slabs shall be a 2 : 1 : 1 mixture of a medium consistency and not sloppy. The jointing concrete must be well tamped into position and brought to the level of adjacent concrete.

Loading Completed Structure.—The contractor shall not at any time load the structure or any part thereof in excess of the designed working load which he may ascertain from the consulting engineer. No load shall be placed on any part of the structure until such part and its supporting members are at least four weeks old, unless such part is otherwise suitably supported.

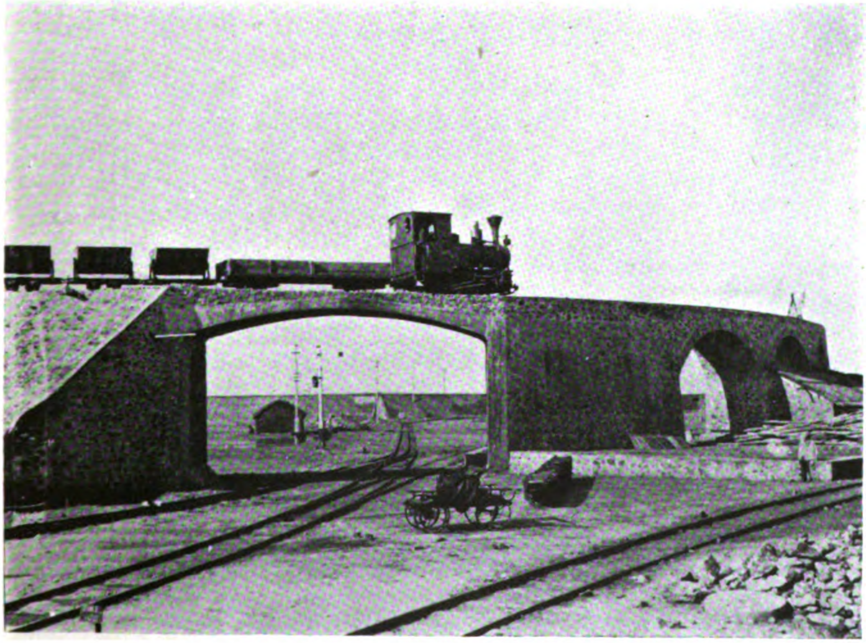
A DOUBLE "C" CANTILEVER BRIDGE.

By S. A. BUNTING, M.A., M.Inst.C.E.

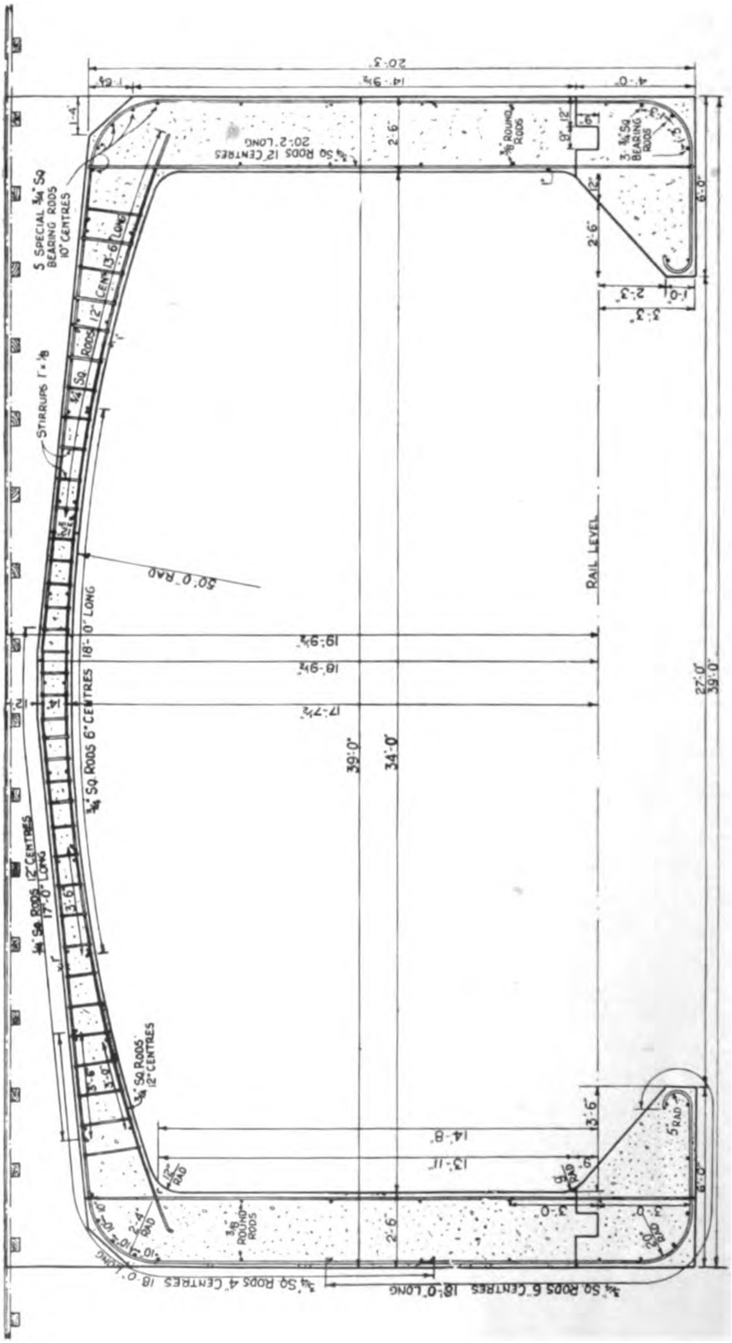
THIS type of bridge is specially adapted to cases where head-room is limited to such a point as to rule out girders or arches below the deck, as well as any structure above deck level. In common with the arch, the two halves are partially maintained in equilibrium by horizontal thrust at the crown, but there the resemblance ceases. The vertical depth from deck level to the springing point is fixed solely with regard to the cantilever stresses due to load on half the bridge; no absolute necessity for a "rise" to the structure, considered as an arch, exists. There are, of course, narrow limits to the economic span of such a bridge, but a span sufficient to pass a street of normal width or a double-track railway is within these limits. The earth pressure of the embankments against the abutments reduces the bending moment in the span.

A successful road bridge of this type of about 40 ft. clear span was recently constructed in New York, the slenderness of the arch outlines being particularly pleasing to the eye. The author decided to adopt the same method at Sambhar, Rajputana, to take a 2-ft. gauge railway (3-ton axle loads) over some metre-gauge sidings, on a skew of 30°, the clear span on the skew being 34 ft. and the vertical distance between rail levels above and below, 19 ft. 9½ in.

In calculating, the middle 11 ft. of the bridge can be treated as a suspended span supported by the two "**C**" cantilevers, but no actual or virtual hinge is



DOUBLE "C" CANTILEVER BRIDGE FOR 2-FT. GAUGE RAILWAY.


20'-3"
14'-9½"
4'-0"
1'-6½"
1'-4"
2'-6"
¾" SQ RODS 12" CENTRES 20'-2" LONG
⅜" ROUND RODS
3-¾" SQ BEARING RODS
5 SPECIAL ¾" SQ BEARING RODS 10" CENTRES
¾" SQ RODS 12" CENTRES 13'-6" LONG
STIRRUPS 1"×⅛"
50'-0" RAD
RAIL LEVEL
19'-9½"
18'-9½"
17'-7½"
39'-0"
34'-0"
27'-0"
¾" SQ RODS 6" CENTRES 18'-0" LONG
¾" SQ RODS 12" CENTRES 17'-0" LONG
¾" SQ RODS 12" CENTRES
14'-8"
13'-11"
3'-6"
6'-0"
2'-3"
1'-0"
3'-3"
5" RAD
12" RAD
20" RAD
2'-4" RAD
¾" SQ RODS 4" CENTRES 18'-0" LONG
¾" SQ RODS 6" CENTRES 18'-0" LONG

DOUBLE C CANTILEVER BRIDGE FOR 2'-0" GAUGE RAILWAY.

allowed; on the contrary, the whole of this centre section must be capable of resisting a heavy bending moment and transmitting it to the cantilevers adjoining, the points of contraflexure being indeterminate.

Treating the two halves as cantilevers, the rest is plain sailing in the bridge till the springing lines are reached. At a springing line the bending moment has to be safely transmitted round a right-angle bend. All that is necessary on the outside of the bend is to take the tension members round on the largest convenient radius, and prevent their cutting into the concrete by suitable transverse bearing members at short intervals round the bend. Knowing the tension and change of angle at any one transverse member, the resultant radial thrust is found and the area of steel required to distribute it on the adjoining concrete. On the compression side, the inner corner must be considered as an arch to resist the radial thrusts above mentioned, the circumferential compressive stresses varying from 600 lbs. per sq. in. or more at the intrados to nil at the extrados or neutral axis. The idea should be to get uniform distribution of these radial thrusts all round the quarter-circle arch, and not to concentrate them as would be done if a sharp inner corner were adopted. A curve of quite small radius is sufficient to reduce this compressive stress in the corner to a possible figure.

The intrados and vertical reinforcing bars which cross at this corner may assist somewhat in taking these compressive stresses, but they are not necessary on that account, and are extended merely to get an anchorage.

The uprights or abutments are reinforced to resist earth pressure from the embankments when there is no load on the bridge; when there is a load on the bridge these inner members are unstressed. On the outside of an abutment the amount of reinforcement necessary is determined by the bending moments at the bottom corner; the excess over this in the upper portion is merely anchorage for the bridge cantilever tension members.

At the bottom corner the same arguments apply as at the top corner; the bending moment to be carried is that due to upward earth pressure on the portion of the footing extending inward towards the centre of the bridge from the face of the abutment. As this extension is only 3 ft. 6 in. and the depth of concrete at the corner is considerable, the tension round the outside of the bend is very much less than that at the top corner, requiring not only less tension metal but a smaller number of transverse members to prevent the tension rods cutting into the concrete. The footing extension is sufficient to reduce the bending moment due to horizontal earth pressure against the abutments to a small figure, by shifting the lower point of contraflexure up the abutment somewhat, but the footing is not intended to sustain the bridge load without the assistance of horizontal thrust at the crown. This function, necessary for a single "**C**" cantilever, would be superfluous and uneconomical here.

The concrete dimensions are such that shear in the footings and abutments can be disregarded, and only shear in the bridge dealt with. As in the case of bending moments, it is impossible to locate points of maximum shear, and the shear members necessary at the assumed points of suspension must be continued undiminished up to the crown, and down nearly to the springing, to a point where the increasing thickness of the concrete can be said to be equal to all possible shear stresses. The shear members have a further function, namely, to prevent tension members in the intrados from pulling out straight under load and so spalling off the intrados concrete.

For the tension members ¾-in. twisted squares were used, and 1 in. by ⅛ in. F.B. for the shear members. These latter were bent over the upper members and under the lower ones in a series of "**V**'s" and "**W**'s." Where the angle with the vertical became excessive, closer spacing was adopted in compensation.

The forms used were sleepers, and they were supported by sleeper cribs, loaded with stone at the sides to resist overturning under the side thrust of the concrete in the abutments. Lime plaster made them smooth and water-tight.

The concreting was done in three instalments. First, the footings were made up to the construction joint shown on the plan, a box being cast in to form a key. Then the abutments were concreted nearly up to the springing lines, a few old fishplates, etc., being stuck in the joint to form a bond. Then the earth was filled in behind the abutments so that easy access to the bridge could be had. The bridge was then concreted as rapidly as possible.

Low masonry parapets were built, these also were bonded on in places by rods and fishplates left projecting from the concrete. Earth and ballast were filled in and the track laid, on a 145-ft. radius curve.

The bridge is, if anything, too heavily designed for the loads, and no measurable deflection occurs. It is evident that had tightness of head-room necessitated it a depth of 3 ft. 6 in. from upper rail level at the springing line and 1 ft. 9 in. at the crown would have sufficed. But the extra weight of ballast and earth is well worth while when head-room can be spared, as the impact stresses are thus made negligible.

STRESSES IN THIN CIRCULAR PIPES, ETC., UNDER SYMMETRICAL LOADS.

I.

By G. P. MANNING, M.Eng., A.M.Inst.C.E.

THE general theory of a thin circular ring under an irregular series of loads, although interesting from the academic standpoint, is of little practical interest since lengthy general equations are of no use to the practical designer. One particular aspect of this problem—namely, the case when the loading is symmetrical about any one diameter—is capable of being reduced to a series of numerical coefficients which can be practically applied, and, since most practical loading is symmetrically placed with regard to at least one diameter, the solution of this particular case will cover nearly every instance which arises in practice.

We shall first solve the case of two movable point loads W acting at right angles to the diameter of symmetry. Then we shall solve the case of two movable point loads acting parallel to the diameter of symmetry. These cases, by extension, cover all and every loading.

Let *Fig.* 1 represent a circular ring *acbd* (or a short length of circular pipe, etc.) carrying two point loads W at right angles to, and symmetrically disposed with regard to, the diameter *ab*.

Consider the equilibrium of the top half of the figure *acb* (shown in full lines) and the reaction of the bottom half (shown dotted) on the top half.

From the conditions of symmetrical loading it is evident that there is no horizontal reaction of one half on the other, either at *a* or at *b*, but there will be reactions at right angles to *ab* and also bending moments.

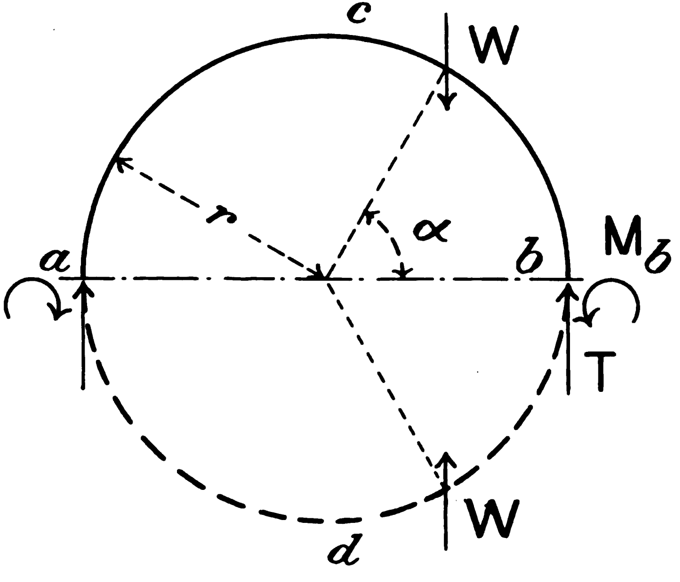


FIG. 1.

Let T = reaction at b of the bottom half on top half.

M_b = bending moment at b reckoned positive when tension occurs on the inside of the ring.

a = angle subtended at the centre (in radians).

r = radius.

EI = deflection coefficient of a cross section of the ring (constant).

Consider the deflections of the top half, *acb*.

By symmetry the tangents at a and at b remain at right angles to *ab*, also a and b remain always in the same original straight line *ab* since neither tends to move at right angles to *ab*. The line *ab* always passes through the centre of the circle. The distance *ab* does not remain constant.

The conditions, therefore, are in some respects similar to those in a semi-circular encastré arch, and we may save time by choosing the equations which apply from the analysis of the semi-circular encastré arch. An analysis of this case will be found in the author's work, *Reinforced Concrete Design*, and we have at once

$$T = \frac{W}{\pi}(\pi - a + \cos a \sin a) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$0 = (M_b\pi + \pi Tr) - Wr[(\pi - a)\cos a + \sin a] \quad . \quad . \quad . \quad (6)$$

[The horizontal thrust H is zero.]

giving

$$M_b = \frac{Wr}{\pi}(1 - \cos a)(\sin a - \pi + a) \quad . \quad . \quad . \quad (6a)$$

Putting $a = 10°$, $a = 20°$, $a = 30°$, etc. in succession in equations (7) and (6*a*), we arrive at the values tabulated in *Table A*.

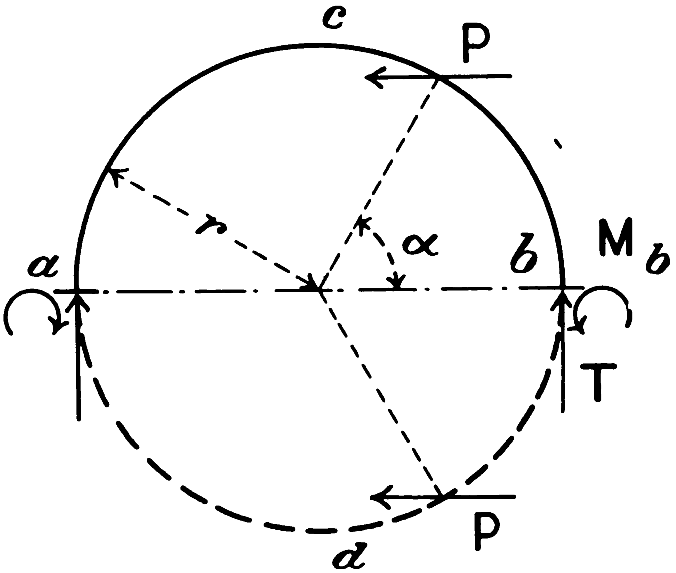


Fig. 2.

For example, if $a = 50^\circ = 0{\cdot}873$ radians,

$$M_b = \frac{Wr}{3{\cdot}1416}(1 - 0{\cdot}6428)(0{\cdot}7660 - 3{\cdot}1416 + 0{\cdot}8730)$$
$$= -0{\cdot}171\ Wr.$$

Coming next to the case where two point loads P acting parallel to ab are applied, we have *Fig.* 2.

We see at once that the system is not in equilibrium and other loads must be applied to prevent actual movement of the whole ring. These, however, can be computed separately and will exist automatically in any practical case.

Choosing those equations of the encastré arch which apply to this case and modifying them as before,

$$T = -\frac{P \sin^2 a}{\pi} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$0 = (M_b\pi + \pi Tr) - Pr(1 + \cos a + a \sin a - \pi \sin a) \quad . \quad . \quad (9)$$

giving

$$M_b = \frac{Pr}{\pi}[\sin^2 a + 1 + \cos a - (\pi - a) \sin a] \quad . \quad . \quad . \quad (9a)$$

Putting $a = 10^\circ$, $a = 20^\circ$, $a = 30^\circ$, etc., as before, we have the values in *Table A*.

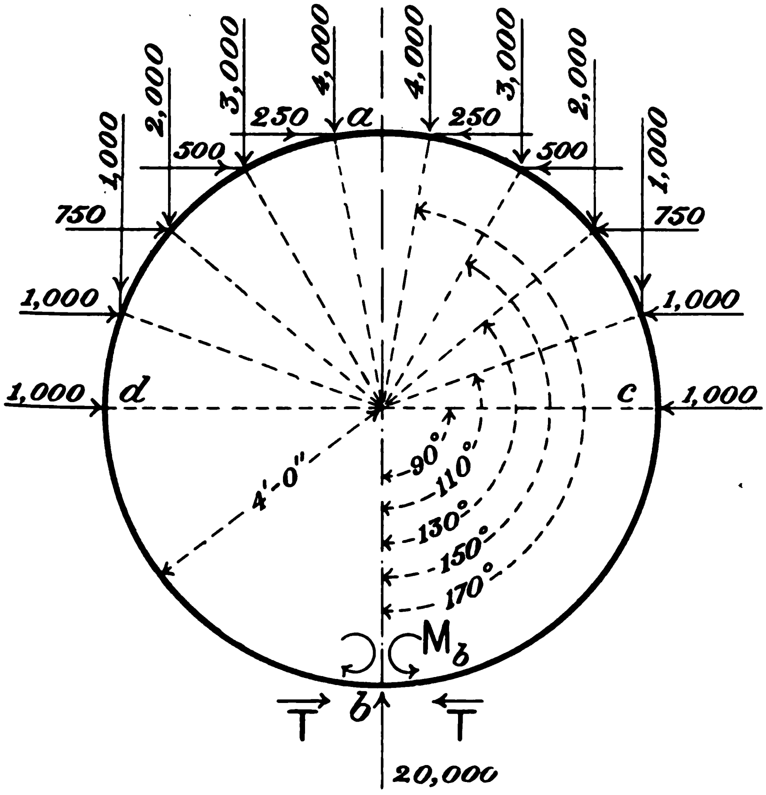


Fig. 3.

TABLE A

CIRCULAR RING, EI = CONSTANT
LOAD SYMMETRICAL ABOUT DIAM. ab.

TWO VERTICAL POINT LOADS ONE ON EACH HALF AS Fig. 1			TWO HORIZONTAL POINT LOADS ONE ON EACH HALF AS Fig. 2.		
α°	M_z	T	α°	M_z	T
0	·0000 Wr	+1·000 W	0	+·6380 Pr	·000 P
10	–·0133 Wr	+·998 W	10	+·4770 Pr	–·010 P
20	–·0468 Wr	+·993 W	20	+·3510 Pr	–·037 P
30	–·0903 Wr	+·970 W	30	+·2570 Pr	–·080 P
40	–·1340 Wr	+·935 W	40	+·1940 Pr	–·131 P
50	–·1710 Wr	+·882 W	50	+·1550 Pr	–·188 P
60	–·1950 Wr	+·806 W	60	+·1400 Pr	–·240 P
70	–·2050 Wr	+·714 W	70	+·1340 Pr	–·282 P
80	–·2000 Wr	+·612 W	80	+·1360 Pr	–·308 P
90	–·1810 Wr	+·500 W	90	+·1360 Pr	–·318 P
100	–·1540 Wr	+·388 W	100	+·1350 Pr	–·308 P
110	–·1205 Wr	+·286 W	110	+·1260 Pr	–·282 P
120	–·0865 Wr	+·194 W	120	+·1095 Pr	–·240 P
130	–·0560 Wr	+·118 W	130	+·0873 Pr	–·188 P
140	–·0309 Wr	+·065 W	140	+·0631 Pr	–·131 P
150	–·0143 Wr	+·030 W	150	+·0388 Pr	–·080 P
160	–·0042 Wr	+·007 W	160	+·0185 Pr	–·037 P
170	–·0006 Wr	+·002 W	170	+·0047 Pr	–·010 P
180	·0000 Wr	·000 W	180	·0000 Pr	·000 P

POSITIVE MOMENTS HAVE TENSION ON INTRADOS
POSITIVE VALUES OF T DENOTE COMPRESSION

One particular case requires special mention. When a point load occurs exactly at *a* (or exactly at *b*) this load must be split into two equal loads, one acting immediately above *a* on the top half of the ring, and the other acting immediately below *a* on the bottom half. This is necessary to comply with our original conditions of symmetrical loading, i.e., that each half of the ring must carry similar (but opposite-handed) loads. Point loads acting in directions opposite to those shown in *Figs.* 1 and 2 must be reckoned negative. Point loads acting in other directions must be resolved into their components. Distributed loads must be grouped into a series of point loads to suit each particular case.

When the moment and thrust at one point have been computed, the moments and thrusts elsewhere can be calculated by simple statics.

The values in *Table A* are given for every 10°, and the reader will find it most convenient to divide the circle into arcs of 20° and imagine all the distributed load on each arc (if any) concentrated at the centre of the arc.

EXAMPLE.—A circular pipe is 8 ft. diameter as shown in *Fig.* 3. It is placed in a trench, being supported on a block of concrete at the foot, and covered to a depth of 20 ft. The earth pressures, etc., per foot run of pipe are computed to be as shown. (These have been chosen at random and do not represent any particular theory of earth pressure.) The loads are symmetrical about a vertical diameter *ab*. What horizontal thrust and what bending moment per foot run of pipe are produced at the lowest point *b* ? [All the loads on the figure are in pounds.]

Note particularly that the load of 20,000 lbs. at point *b* must be looked on as two loads of 10,000 lbs. each, one of which acts on the left-hand half *adb* and the other on the right-hand half *acb*. (If we assumed that the whole 20,000 lbs. acted on one half and nothing acted on the other, then the loading would not be symmetrical and we should violate our first conditions.)

Taking the half circle *acb* and putting everything in pounds and feet, we have :—

(1) A load of + 10,000 lbs. subtending an angle of 0° acting parallel to *ab*.

This causes a bending moment at *b* of M_b where $M_b = +\ 0{\cdot}6380\ Pr$ (see *Fig.* 2 and *Table A*) where $P = +\ 10{,}000$ lbs. (positive because acting in the same direction as P shown in *Fig.* 2).

$$\begin{aligned} r &= 4 \text{ ft.} \\ M_b &= +\ 0{\cdot}6380 \times (+\ 10{,}000) \times 4 \text{ lbs. ft.} \\ &= +\ \underline{25{,}500 \text{ lbs. ft.}} \\ T \text{ (due to this load)} &= 0. \end{aligned}$$

(2) A load of + 1,000 lbs. (positive because acting in the same direction as W shown in *Fig.* 1) subtending an angle $a = 90°$.

$$\begin{aligned} M_b \text{ (due to this load)} &= -\ 0{\cdot}1810\ Wr \text{ (see \textit{Table A})} \\ &= -\ 0{\cdot}1810 \times (+\ 1{,}000) \times 4 \\ &= -\ \underline{724 \text{ lbs. ft.}} \\ T \text{ (due to this load)} &= +\ 0{\cdot}500\ W \\ &= +\ 0{\cdot}500 \times (+\ 1{,}000) \\ &= +\ \underline{500 \text{ lbs.}} \end{aligned}$$

It saves work if the loads are tabulated as shown below :—

Loads acting at right angles to *ab*.

Load.	Angle *a*.	M_b.	*T*.
+ 1,000 lbs.	90°	− 724 lbs. ft.	+ 500 lbs.
+ 1,000 ,,	110°	− 482 ,,	+ 286 ,,
+ 750 ,,	130°	− 168 ,,	+ 89 ,,
+ 500 ,,	150°	− 29 ,,	+ 15 ,,
+ 250 ,,	170°	− 1 ,,	+ 1 ,,
3,500 lbs.		− 1,404 lbs. ft.	+ 891 lbs.

Loads acting parallel to *ab*.

Load.	Angle *a*.	M_b.	*T*.
+ 10,000 lbs.	0°	+ 25,500 lbs. ft.	0 lbs.
− 1,000 ,,	110°	− 504 ,,	+ 282 ,,
− 2,000 ,,	130°	− 700 ,,	+ 376 ,,
− 3,000 ,,	150°	− 466 ,,	+ 240 ,,
− 4,000 ,,	170°	− 75 ,,	+ 40 ,,
0		+ 23,755 lbs. ft.	+ 938 lbs.

The total moment $M_b = + 23{,}755 - 1{,}404 = \underline{+ 22{,}351 \text{ lbs. ft.}}$ (having tension on the intrados)

Total thrust $T = + 891 + 938 = \underline{+ 1{,}829 \text{ lbs.}}$ (compression) both values being per foot run of pipe.

The bending moment at *c* is (by statics)

$$\begin{aligned} &+ 22{,}351 + 1{,}829 \times 4 - 10{,}000 \times 4 \\ &= + 29{,}667 - 40{,}000 \\ &= - \underline{10{,}347 \text{ lbs. ft.}} \text{ (tension on extrados).} \end{aligned}$$

A STUDY OF LOADING TESTS ON REINFORCED CONCRETE STRUCTURES.

By **EWART S. ANDREWS, B.Sc., M.I.Struct.E., A.M.Inst.C.E.**

(II) BRITISH TESTS ON ONE-WAY HOLLOW TILE FLOORS.

We will next study the results of some tests made by the Building Research Board of H.M. Department of Scientific and Industrial Research. The results of tests upon these and other floors will be found in a report entitled "Experiments on Floors," * which gives the results of tests carried out upon light floors which might be regarded as substitutes for timber floors ; students and designers are strongly advised to study this report in respect of all the floors tested.

We will choose for our study two forms of hollow-tile floors with reinforcement running one way which were tested as simply-supported slabs.

First Form of Floor Slab (Type "A" of Report).

As will be seen from *Fig.* 1, this floor consists of hollow tile blocks 10 in. by 6⅝ in. by 4 in. laid in longitudinal rows about ¾ in. apart, but close together endways, set in Portland cement mortar 1 and 3. Slabs were cast in units composed of two rows of tiles with a reinforcing bar between them ; these units were made on planks laid on the ground and, after setting, were placed on the supporting walls. Rods were then placed in the gaps between the three units and the spaces between them were filled with cement mortar which was also placed on the top, ½-in. roofing tiles being bedded in as indicated in *Fig.* 1.

Test Results.—The slab was first covered with sand upon which concrete blocks were placed. The dead load of the slab was 40·6 lbs. per sq. ft. The floor failed at a total superimposed load of 7,413 lbs., the test being made when the units were 117 days old and the completed slab 86 days old.

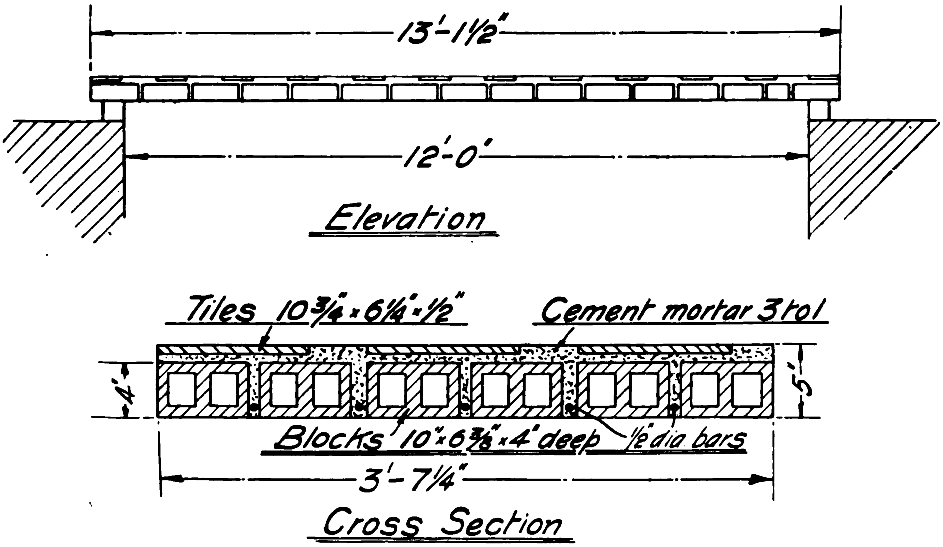


Fig. 1.

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* H.M. Stationary Office. Price 1*s.* 3*d.*

Failure occurred slowly, and examination after failure showed that the cement covering had crushed in the centre (where a crack occurred) at a superimposed load of 5,097 lbs.; the tile covering was broken on each side of the crack, the tiles being lifted from their bed and the hollow tiles cracked through. The reinforcing rods had elongated slightly and were reduced in diameter by 0·2 mm.

The reinforcing bars were hooked at their ends, were 0·52 in. in diameter, and had a yield point of 43,200 lbs. (19·3 tons) per sq. in., and an ultimate strength of 57,600 lbs. (25·7 tons) per sq. in.

Tests made upon the hollow blocks showed a crushing strength of 2,950 lbs. per sq. in. of net area. Tests showed that the cement complied with the British Standard Specification.

CALCULATION OF STRESSES.—We will treat the slab as a series of reinforced concrete **T**-beams and follow the usual textbook practice of making no allowance for the strength of the hollow tiles. The embedded tiles we will allow as at least equivalent in compressive strength to concrete.

We therefore have a depth of slab (*ds*) of 1 in., an effective depth (*d*) of 4·25 in., a breadth of slab of 43·2 in., and an area of reinforcement *A* (that of 5 bars 0·52 in. in diameter, i.e. 1·05 sq. in.).

Using the usual formulæ for **T**-beams, and adopting the standard notation, we have :—

$$\text{Slab depth ratio} = s_1 = \frac{ds}{d} = \frac{1}{4{\cdot}25} = 0{\cdot}235$$

$$\text{Reinforcement ratio} = r = \frac{A}{bd} = \frac{1{\cdot}05}{43{\cdot}2 \times 4{\cdot}25} = 0{\cdot}0057$$

Neutral axis depth ratio

$$n_1 = \frac{2mr + s_1^2}{2(mr + s_1)}$$

$$= \frac{30 \times 0{\cdot}0057 + 0{\cdot}055}{2(15 \times 0{\cdot}0057 + 0{\cdot}235)}$$

$$= \frac{0{\cdot}226}{0{\cdot}640} = 0{\cdot}353$$

$$\therefore n = 0{\cdot}353 \times 4{\cdot}25 = 1{\cdot}5$$

Distance of centre of compression from top edge

$$= \frac{ds}{3}\frac{(3n_1 - 2s_1)}{(2n_1 - s_1)}$$

$$= \frac{1}{3}\frac{(1{\cdot}059 - 0{\cdot}47)}{(0{\cdot}706 - 0{\cdot}235)}$$

$$= 0{\cdot}42$$

$$\therefore \text{Lever arm} = a = 4{\cdot}25 - 0{\cdot}42 = 3{\cdot}83 \text{ in.}$$

It will be noted that the simple approximate rule $a = d - 0{\cdot}4ds$ gives $a = 3{\cdot}80$, which is sufficiently close for all practical purposes.

We will now estimate the stresses in the material at the failure load on the assumption that the ordinary theory holds true up to failure. The effective span is 12·3 ft. and the superimposed load is 7,413 lbs., to which we must add the dead weight of $40{\cdot}6 \times 12{\cdot}3 \times 3{\cdot}6 = 1{,}800$ lbs., giving $W = 9{,}213$ lbs.

$$\therefore \text{ Bending moment } = B = \frac{9{,}213 \times 12{\cdot}3 \times 12}{8} = 170{,}000 \text{ in.-lb.}$$

$$\therefore \text{ Stress in steel} = \frac{\text{Bending moment}}{\text{Area of steel} \times \text{lever arm}} = \frac{170{,}000}{1{\cdot}05 \times 3{\cdot}83}$$

$$= 42{,}300 \text{ lbs. per sq. in.}$$

This is practically equal to the yield point of the steel as shown by test.

Total compression in concrete

$$= C = \frac{\text{Bending moment}}{\text{Lever arm}} = \frac{170{,}000}{3{\cdot}83}$$

$$= 43{,}400.$$

But if c is the maximum stress in the concrete,

$$C = b.d_s\left(1 - \frac{s_1}{2n_1}\right)c$$

Taking b in this case as 40 in., we have

$$C = 40 \times 1\left(1 - \frac{0{\cdot}235}{0{\cdot}706}\right).c$$

$$= 26{\cdot}7c$$

$$\therefore c = \frac{43{,}400}{26{\cdot}7} = 1{,}630 \text{ lbs. per sq. in.}$$

We will next calculate the design load on the assumption that steel can carry one-fourth of its ultimate strength and that the concrete can be stressed to 650 lbs. per sq. in. For the steel we should have a stress of 14,400 lbs. per sq. in., and the inclusive load W_s will be

$$W_s = \frac{9{,}213 \times 14{,}400}{42{,}300} = 3{,}130 \text{ lbs.}$$

For the concrete we should have a load W_c given by :—

$$W_c = \frac{9{,}213 \times 650}{1{,}630} = 3{,}680 \text{ lbs.}$$

The steel clearly determines the load, and as the dead load is 1,800 lbs., the safe superimposed load becomes $3{,}130 - 1{,}800 = 1{,}330$. This corresponds to about 30 lbs. per sq. ft., and is too small even for domestic purposes.

It will be noted that the load test factor, namely, the ultimate inclusive load divided by the design inclusive load (sometimes called the "actual factor of safety"), is $\frac{9{,}213}{3{,}130} = 2{\cdot}94$. This is approximately what we should expect in a case such as this.

SECOND FORM OF FLOOR SLAB (TYPES "C" AND "G" OF REPORT).

We will also consider the results of two tests made upon the floor shown in

Fig. 2. This floor was in many respects similar to that which we have already considered, each being hollow-tile floors formed of pre-cast units concreted over after placing in position. These floors are often advocated on the ground that they avoid the use of centering.

The floor now under consideration was formed of hollow tiles 16 in. by 9½ in. by 5 in. provided with side grooves for housing reinforcing bars. Units were made on the ground by placing blocks end to end and laying ⅜-in. steel rods in the grooves ; cement mortar 1 and 3 was placed between the blocks and in the grooves. The units thus made were then placed in position and 1 in. of fine cement concrete was placed over the tiles and in the spaces between them.

One test (slab " G ") was made when the units were 46 days old, and the complete floor slab 32 days old ; the other test (slab " C ") was made with the units 137 days old and the complete floor 71 days old. The weight of the floor was 52·5 lbs. per sq. ft.

TEST RESULTS.—The two floors failed at practically the same superimposed load, viz. 6,642 and 6,350 lbs. The yield point of the steel was 22·4 tons (50,000 lbs.) per sq. in.

A 6-in. cube of the concrete used was tested at 90 days and showed an ultimate strength of 2,440 lbs. per sq. in. After a superimposed load of 2,116 lbs. (70·5 tons) per sq. ft. had been put on the deflection in the case of slab " C " was 0·05 in., and on removing the load this deflection returned to zero.

The slab fell about 8 in. on to a stop at failure ; the concrete covering had crushed at the centre where the fracture occurred and had lifted and parted from the blocks. The rods did not appear to have slipped, and must therefore have elongated sufficiently to permit failure of the slab.

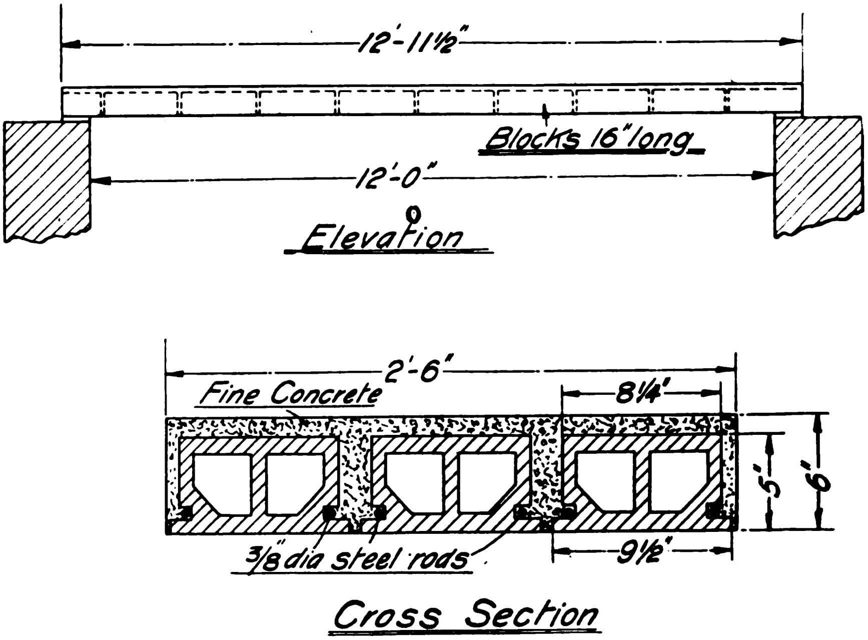


FIG. 2.

In the case of slab "G" the deflection was 0·08 in. at a superimposed load of 75·5 lbs. per sq. ft., and on removing this load a permanent set of 0·05 in. was found. This slab broke at the centre and the rods had drawn down to $\frac{5}{16}$ in. diameter and the top coat of fine concrete had crushed and pushed upwards for a width of about 10 in. on each side of the crack; the tile slab was cracked right through and had crushed at the top and opened out about $\frac{1}{4}$ in. at the bottom.

Fig. 3 shows the load-deflection curves in the two cases drawn on the same base. It will be seen that the deflections in the earlier stage of the loading were greater in the case of the younger slab "G."

Calculation of Stresses.—We will apply a similar treatment to that which we employed in the other case by treating the slab as a series of T-beams.

In this case the total breadth (b) of the slab we take as 30 in., and the depth (d_s) of the slab as 1 in. The effective depth d of the beam is 5 in., and the area A of the reinforcement (6 — $\frac{3}{8}$ in. bars) is 0·662.

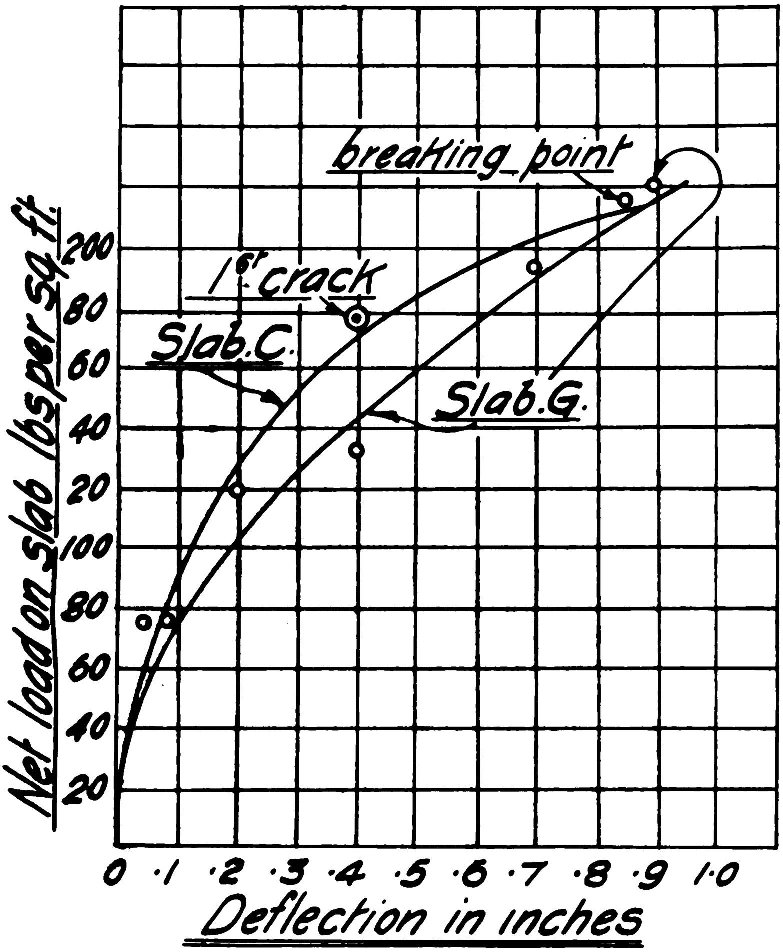


Fig. 3.

Taking the approximate formula for the lever-arm, viz. $a = d - 0\cdot4d_s$, we have

$$a = 4\cdot6 \text{ in.}$$

This will be found to be in good agreement to the value obtained by the more rigid formulæ given in the case of the slab previously considered.

The effective span we take as 12·5 ft., and to the ultimate superimposed load of 6,350 lbs., we add the dead load of the slab, viz. 52·5 by 12·5 by 2·5 = 1,640 lbs., giving a total failure load

$$W = 7{,}990 \text{ lbs.}$$

∴ Maximum bending moment at failure

$$= B = \frac{7{,}990 \times 12\cdot5 \times 12}{8} = 150{,}000 \text{ in.-lb.}$$

∴ Stress in steel at failure

$$= t = \frac{\text{Bending moment}}{\text{Area of steel} \times \text{lever arm}}$$

$$= \frac{150{,}000}{\cdot662 \times 4\cdot6} = 49{,}300 \text{ lbs. per sq. in.}$$

This again is practically equal to the yield point stress of the steel as shown under test (50,000).

To investigate the stress in the concrete just before failure we must first find the position of the neutral axis. This is given by the formula :—

Neutral axis depth ratio $\left(\frac{n}{d}\right)$

$$= n_1 = \frac{s_1^2 + 2mr}{2(s_1 + mr)}$$

In this formula $s_1 = \frac{1}{5} = \cdot2$; $m = 15$, and $r = \frac{\cdot662}{30 \times 5} = 0\cdot0044$

$$\therefore\ n_1 = \frac{0\cdot04 + 0\cdot132}{2(0\cdot2 + 0\cdot066)} = 0\cdot324$$

$\therefore\ n = 0\cdot324 \times 5 = 1\cdot62$ in.

∴ Total compression in concrete

$$= C = b\cdot ds\left(1 - \frac{s_1}{2n_1}\right)c = 30\left(1 - \frac{0\cdot2}{0\cdot648}\right)c = 20\cdot7c.$$

$$\text{But } C = \frac{\text{Bending moment}}{\text{Lever arm}} = \frac{150{,}000}{4\cdot6} = 32{,}600$$

$$\therefore\ c = \frac{32{,}600}{20\cdot7} = 1{,}570 \text{ lbs. per sq. in.}$$

This is considerably less than the value given by the cube test, so we may infer that failure was really caused by the yield of the steel which caused the neutral axis to move upwards and thus caused the force C to be carried by a smaller area so bringing the stress up to the crushing strength of the concrete.

We now come to the question of what we should consider to be the design load for the floor. Taking the steel as capable of carrying safely a tensile stress of 16,000 lbs. per sq. in., we shall have for the design load for the steel

$$W_s = \frac{7{,}990 \times 16{,}000}{49{,}300} = 2{,}590 \text{ lbs.}$$

For the concrete at 650 lbs. per sq. in. we shall have

$$W_c = \frac{7{,}990 \times 650}{1{,}570} = 3{,}310 \text{ lbs.}$$

Adopting the steel value and deducting the dead load of 1,640 lbs. we have left a design superimposed load of 850 lbs., which corresponds to 27·2 lbs. per sq. ft., and is too small even for light floors for domestic purposes.

Now let us see what load per sq. ft. corresponds to a load test factor of 4 upon the failure load. One-fourth of the inclusive load gives 2,000 lbs., and after deducting the dead load of 1,640 this leaves only 360 lbs., or about 11·5 lbs. per sq. ft.

On the whole the results of the tests made upon the two forms of reinforced slabs agree very well with the results one would have expected to obtain from applications of the ordinary theoretical formulæ. It would have been very interesting if corresponding tests had been made upon the same type of slabs with much stronger reinforcement; we are inclined to the belief that relatively higher results would have been obtained in such a case.

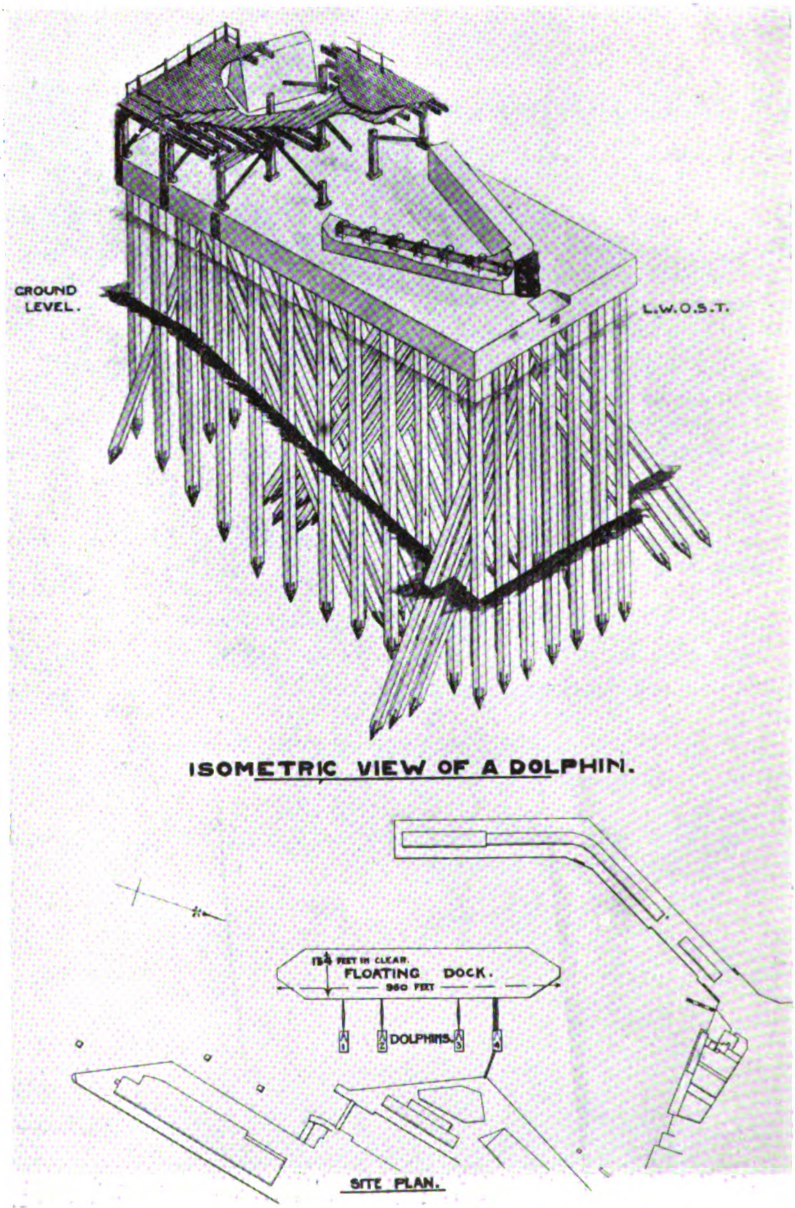
GENERAL DEDUCTIONS.

We think that the following facts can be deduced from these tests :—

(1) That more or stronger reinforcement could with advantage have been provided.

(2) That the failure occurred when the steel reached the yield point stress, after which the neutral axis moved upward and the concrete became overstressed in compression.

(3) That the designs of floor are not strong enough for spans of 12 ft. even for light floors for domestic purposes.



[*Mr. F. E Wentworth-Sheilds, O.B.E., M.Inst.C.E., Engineer.*

REINFORCED CONCRETE DOLPHINS FOR A 60,000-TON FLOATING DOCK AT SOUTHAMPTON.

(*See p.* 451.)

REINFORCED CONCRETE DOLPHINS FOR 60,000-TON FLOATING DOCK AT SOUTHAMPTON.

One of the indirect results of the war is that the largest products of the German shipyards now make their home under the British flag at Southampton. That they should be found at Southampton is natural, for a growing realisation of the unique advantages of Southampton to shipping of all classes, and in particular to the largest ocean liners, has been the result of increased experience gained during the years of the war.

Among the boats so sailing are the *Majestic* of 56,557 tons, the largest boat in the world, and the *Homeric*, which claims the distinction of being the largest twin-screw boat so far built, both of which are now in the White Star Service ; while the Cunard Line have also the *Berengaria* of 52,700 tons.

The Docks at Southampton are the property of the Southern (late London & South Western) Railway, and it is in keeping with that Company's policy in the past that the advent of the ex-German ships found them able to offer adequate dry dock facilities for all boats except the *Majestic*, and determined to remedy even this limitation. They therefore decided to supplement the two large graving docks already in existence—No. 5, " Prince of Wales," and No. 6, " Trafalgar "—by a still larger floating dock able to deal with the *Majestic*, or any other ship so far conceived, for repairs and overhaul.

The site selected is to the extreme west of the existing docks, where it is well sheltered from the worst winds, and out of the main flow of the tide ; it is at the same time adjacent to the works of one of the largest ship-repairing firms and also easily accessible to the yards of the others. But suitable as the site was in these directions it had not the great depth of water required for a dock of this size and type, and extensive dredging was undertaken by the London & South Western Railway Company for the removal of about 1,000,000 yards of stiff clay, and very hard green sand to the depth of 61 ft. below L.W.O.S.T., or 80 ft. below quay level, to provide a berth for the dock.

As will be seen by reference to the illustration, the site, suitable as it is, does not allow of the dock being moored by anchors and cables owing to the proximity of the Town Quay and Berths Nos. 50 and 51. Other arrangements, therefore, had to be devised to keep the dock in position. Mr. F. E. Wentworth-Sheilds, O.B.E., M.Inst.C.E., the Docks Engineer, therefore designed a series of dolphins, four in number, in reinforced concrete, to which the dock is fixed by long steel booms, so avoiding the need for the usual side moorings.

The dolphins are spaced in pairs at 130 ft. 3 in. centres, with 260 ft. 6 in. between the two inner dolphins. The floating crane of 150-tons capacity which will be in attendance on the dock will be enabled to lie between each pair of dolphins and to move with facility to the amidships section of the dock.

The range of tide at Southampton is about 13 ft. at " Springs," and in addition to this the docking draught of the boats of the type for which the dock is intended will be at least 36 ft., so that, relative to the dolphins, a considerable range of level occurs in the dock. The contract for these dolphins was placed with Messrs. A. Jackaman & Son, Ltd., engineers and contractors, of Slough, who have now completed the work.

The dolphins stand in four specially-dredged pockets cut in the 3 to 1 slope in the east or dock face of the deep berth for the floating dock. The level of the bottom of the pockets is 32 ft. below L.W.O.S.T.

Reference to the drawing shows that each of the four dolphins consists of 94 reinforced concrete piles, penetrating up to 23 ft. into hard clay boulders and very compact sand. The deck is a massive slab of reinforced concrete 70 ft. long, 32 ft. wide, and 5 ft. thick, in which the heads of the piles are embedded.

These piles vary in length from 47 ft. to 66 ft. and are all 16 in. by 16 in., in every case reinforced by four $1\frac{3}{8}$-in. diameter rods, the rods being linked together by pre-formed links of $\frac{3}{16}$-in. diameter. In view of the hard driving expected the shoes are of a particularly heavy pattern and are cored out to take three water jets, connection to which is made by a wrought-iron pipe down the centre of the pile through which high pressure water was passed as driving proceeded.

A particularly good mixture of concrete, viz. 1 : 1½ : 2½, has been used for the piles.

In view of the very severe racking action to which the dolphins may be subjected by wind pressure on the dock and from other causes, it was necessary that 50 of the internal piles in each dolphin should be driven at a batter of 60 degrees. The vertical piles, which vary in length from 60 ft. at the front of the dolphin to 47 ft. at the back, are spaced around the edge of the slab with an additional row at the front and back. Between the two back rows of vertical piles, two transverse raking piles each 53 ft. long are driven, one in each direction ; and between the two front rows of vertical piles, six transverse raking piles, each 66 ft. long, are driven, three in each direction. Forty-two other battering piles are driven longitudinally to the axis of each dolphin to take the " push " and " pull " of the dock.

These battering piles are in two groups arranged respectively at the front and the back of the dolphin, each group consisting of three rows of seven piles per row, the front group of piles, 66 ft. long, raking from the front to the back with a penetration of 14 ft., and the back group of an equal number also arranged in three rows of seven piles sloping from the back to the front with a penetration of 21 ft.

Temporary timber staging to carry the pile engines for driving the permanent reinforced concrete piles was erected in the usual way, each dolphin being staged for separately, and between each pair an independent staging was erected to carry a 10-ton derrick crane, with a jib long enough to reach every part of the pair of dolphins.

The piles were moulded on a vacant site at Berth No. 45, under the shadow of the giant liners for whose service they were being prepared. When mature they were conveyed by barge to the site of the works for driving.

The pile engines, which were specially designed by the contractors to drive the vertical piles as well as the raking piles in all the four directions, were of steel, and were carried on steel gantry girders to facilitate adjustment to any part of the dolphin.

A steel mast 66 ft. long was used to enable the raking piles to be pitched truly and to support them during driving, this being of sufficient strength to take the weight of the pile in addition to that of the monkey, etc., and could be so adjusted that the lower end was beyond the centre of gravity of the pile when pitched. The masts also served as false leaders, as it frequently happened that 45 ft. of the pile was below water before driving started. It was very necessary to guide the piles at the lowest possible level, and for this purpose the masts were also quite successful. After considerable inquiry, it was decided to use a 3-ton semi-automatic steam hammer, and this has given satisfaction alike in the vertical driving and on the batter piles.

The driving of the vertical piles presented no particular difficulty save that they had to be pitched in a very considerable depth of water. On the other hand, the driving of the batter piles presented several problems of interest. The pitching of the batter piles involved certain difficulties ; for instance, the different levels of the tide affected the slope at which the pile hung in the slings owing to the loss of weight of the immersed portion of the pile, and also it was necessary to release the lower sling in 25 to 30 ft. of water, for which naturally the services of a diver were not desired. But these difficulties were overcome.

On the whole, the driving proceeded in a satisfactory manner, but great difficulties were experienced with No. 2 Dolphin consequent on the presence of obstruction encountered during the driving. As a consequence certain rearrangements of piles, etc., in that dolphin were necessary. As result of experience gained, the use of water pressure was not always resorted to, but it was always in reserve for use if required.

When the mast was removed from the raking piles after driving these piles had to be supported, as the overhanging length of 45 ft. above the ground was obviously excessive. In the case of the main rakers this was accomplished by driving at both ends of the dolphin at the same time, using two pile engines and tying the opposite piles to each other. One rather unexpected result was that the penetration per blow was found to be greater in the raking piles than in the vertical piles when the shoes were at the same level. This was found to be the case regardless of the use of water pressure or not. Careful experiment showed that the weight of the pile was sufficient to prevent any considerable tendency for the toe to run outwards during the operation of driving. But this contingency was considered.

Driving being completed, the heads of the piles were stripped for a length of 3 ft. and incorporated in the slab of reinforced concrete referred to above (1 : 4 mixture), 70 ft. long, 32 ft. wide, and 5 ft. thick. The slab was reinforced top and bottom with a meshwork of 1⅛-in. diameter rods. At the bottoms the rods were at 10½-in. centres longitudinally and 11 in. transversely, and at the top of the slab a like reinforcement was arranged, the top longitudinal rods being at 8-in. centres and the transverse rods at 18-in. centres. The longitudinal rods were bent down at both ends to assist the beam action on the slab.

The underside of the slab being only 5 ft. above Low Water Ordinary Spring Tides and the top well below High Water Neap Tides, the execution of the work was necessarily slow.

Between the raking piles under the ends of the slab there was an area in the central portion of about 50 ft. by 28 ft. for which no support was afforded by the permanent piles. The slab had a weight of rather over 10 tons per ft. run forward, and as the side vertical piles, which were the only available support, were at 6 ft. 4 in. centres, each strip of slab carried by two piles weighed about 68 tons and the shuttering to carry this load to the piles was not an easy matter, particularly when the level of the lowest low water is remembered.

The actual concreting presented no interesting features. It was not possible to pour the slabs from the quay as the necessary guy lines to the tower, etc., were impracticable owing to the interference they would have caused to the traffic of the dock. The concrete was, therefore, mixed afloat and placed by crane. The work was, of course, strictly tidal and carried out by day and night as the tides permitted, each slab taking about three weeks.

For these slabs, selected Langstone ballast was used, as it rose, without grading or crushing. The usual precautions were taken at all meeting faces between new and old concrete, even if the old concrete had only been placed a few hours.

These four heavily-piled slabs form the anchorage for the dock. The actual connection of the floating dock to them is as follows :—Steel castings weighing 5 tons 16 cwts. each are set on the top of each slab near the front edge, and from these steel booms 110 ft. long connect the floating dock to the dolphins, the attachment to the casting being made by pins 8¼ in. in diameter. From the back of the castings two arms radiate—each consisting of two mild steel plates 27 ft. long, 16 ins. deep, and ¾ in. thick. The centre of these plates is about 2 ft. 6 ins. above the top of the slab.

From the main slab a number of " hairpins " of 1½-in. diameter steel bars project vertically upwards on both sides of these wing plates and transmit the stresses from them to the slab.

The main slab having been suitably prepared to receive it, the wing plates were incorporated in an upward extension of the slab 5 ft. 6 in. high and 3 ft. thick along their length, thus connecting, through the reinforcement, the actual casting and the main slab.

The dolphins are covered at high water, and to indicate their positions, etc., dolphins 1, 2, and 3 are fendered or fenced to 6 ft. above High Water Ordinary Spring Tides with creosoted pitch pine timber, curbed at the top with the same material, the fencing being suitably strutted to the slab with old rail bracings and ties.

Dolphin No. 4 is utilised to give access to the floating dock, since it is the nearest dolphin to the quay wall. It has a creosoted pitch pine staging erected on it, access to which is given by a lattice steel bridge from the quay wall.

From the dolphin a hinged bridge gives access to the top of the dock walls, while a gangway constructed on the boom gives access to the floor of the dock, when the dock is raised, by a portal opening through the wall.

Reference has already been made to the special pockets or benchings cut on the general slope of the dredged area for the dock. On completion of the dolphin these were filled in again with Langstone ballast fed in from barges by chutes under the dolphin, thus adding to the stability of the whole structure. A bank of rubble stone was also deposited at the front of each dolphin.

These dolphins are a novel and interesting application of reinforced concrete construction to sub-aqueous structures, and will form the anchorage for the largest floating dock in the world, which has been constructed by Sir W. G. Armstrong Whitworth & Co., Ltd., at their Walker-on-Tyne Yard. The dock has a length of 960 ft., the overall height of the side wall is 70 ft. 6 in., the clear width of the entrance is 134 ft., and the draft of water over the keel blocks is 38 ft. 6 in. The estimated nett weight of the dock is 18,000 tons, and its lifting capacity 60,000 tons, while the area of the pontoon is 142,000 sq. ft., or nearly three acres.

Built in seven sections, the dock is of the double-sided self-docking or sectional box type. To lift a 52,000-ton ship 32 ft. 9 in. in four hours, the fourteen electric pumps will have to discharge 80,000 tons of water, the total electric pumping energy being about 1,250 KW.

The reinforced concrete dolphins have been constructed by Messrs. A. Jackaman & Son, Ltd., of Slough. Mr. R. N. Sinclair, M.Inst.S.E., supervised the work on behalf of the Railway Company.

QUESTIONS AND ANSWERS RELATING TO REINFORCED CONCRETE.

Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—ED.

SALTPETRE AND CONCRETE.

QUESTION.—Will you please let me have your opinion about destroying saltpetre in the soil of canal banks ?—S. S.

ANSWER.—This question is rather vague, but one may assume it to mean that the soil on canal banks contains saltpetre which attacks concrete used in connection with a canal. If this is the case, we can suggest no means of destroying the saltpetre, but its action on concrete could be minimised by mixing the concrete dense, i.e. by using a very rich concrete with a well-graded aggregate so that the concrete is impervious to soil.

CONCRETE AND THE PUBLIC.

A CINEMATOGRAPH film, entitled "The Story of Concrete," is now being shown at cinematograph theatres throughout the country, and may be seen at the following places on the dates given : St. George's Hall, Falmouth, July 17 (3 days) ; Picture de Luxe, Newlyn, July 24 (3 days) ; Gaiety de Luxe, Hayle, July 27 (3 days) ; Prince's Theatre, Accrington, August 11 (3 days) ; Druid's Hall, Redruth, August 18 (3 days) ; Picture Palace, Bramley, August 28 (3 days) ; Assembly Hall, Winchcombe, September 11 (3 days).

STRUCTURAL STEELWORK REINFORCED WITH CONCRETE.

Dr. Markus Reiner, of the Public Works Department, Jerusalem, has sent us the following communication regarding the article on "Structural Steelwork Reinforced with Concrete," by Mr. Ewart S. Andrews, in our January issue :—

Sir,—In your January issue Mr. E. S. Andrews discusses certain Canadian experiments on concrete-encased steel joists. In the course of this discussion he gives the calculation of such a beam under the assumption that the resistance of concrete to tension is to be neglected. He then finds that the actual load to produce a stress of 16,000 lbs. per sq. in. in the steel was considerably higher than that calculated, and comes to the conclusion that the increase of strength found on test may be due to the actual tensile resistance of the concrete.

This is a somewhat astonishing conclusion. Does it mean that Mr. Andrews thinks concrete can bear a tensile stress of something like $\frac{16{,}000}{15} = 1{,}066$ lbs. per sq. in. ?

Below you will find the extension of Mr. Andrews' calculations for the case of full tension in the concrete.

Assuming the breadth of the web at underside of slab being $b^1 = 11\frac{1}{2}$ and denoting with d_s the slab-thickness, we have this equation from the rule of moments :

$$(b - b^1)\,d_s\left(n - \frac{d_s}{2}\right) + b^1\left[\frac{n^2}{2} - \frac{(d_t - n)^2}{2}\right] = mA(d - n)$$

or

$$n\,[(b - b^1)d_s + b^1 d_t + mA] = (b - b^1)\frac{d_s^2}{2} + b^1\frac{d_t^2}{2} + mAd$$

This gives :

$$n = \frac{36{\cdot}5 \times \frac{4^2}{2} + 11{\cdot}5 \times \frac{13^2}{2} + 15 \times 6{\cdot}5 \times 8}{36{\cdot}5 \times 4 + 11{\cdot}5 \times 13 + 15 \times 6{\cdot}5} = 5{\cdot}2 \text{ in.}$$

The equivalent moment of inertia is :

$$= I_E = \frac{b}{3}[n^3 - (n - d_s)^3] + \frac{b^1}{3}[(n - d_s)^3 + (d_t - n)^3] + m[I + A(d - n)^2]$$

$$= \frac{48}{3}(5{\cdot}2^3 - 1{\cdot}2^3) + \frac{11{\cdot}5}{3}(1{\cdot}2^3 + 7{\cdot}8^3) + 15\,(114 + 6{\cdot}5 \times 2{\cdot}8^2) = 6{,}510 \text{ in.}^4$$

∴ equivalent tension modulus of section

$$= M_T = \frac{I_E}{m(d_t - n)} = \frac{6{,}510}{15 \times 7{\cdot}8} = 55{\cdot}5 \text{ in.}^3$$

and compression modulus

$$= M_C = \frac{I_E}{n} = \frac{6{,}510}{52} = 1{,}250 \text{ in.}^3$$

The stresses are therefore :

$$\text{tensile stress on steel} = t_s = \frac{B}{55{\cdot}5}$$

$$\text{tensile stress on concrete} = t_c = \frac{B}{15 \times 55{\cdot}5}$$

$$\text{compressional stress on concrete} = C = \frac{B}{1{,}250}$$

B being the bending moment.

It should be noted that these formulæ can be applied only up to the tensile strength of concrete, which may be assumed at about 340 lbs. per sq. in. That means that the maximum bending-moment is $B = 15 \times 55{\cdot}5 \times 340 = 283{,}000$ in.-lbs. and the maximum weight

$$W = \frac{8B}{l} = \frac{8 \times 283{,}000}{16 \times 12} = 11{,}800 \text{ lbs.}$$

$$\text{i.e. weight per sq. ft.} = \frac{11{,}800}{5 \times 16} = 148 \text{ lbs.}$$

The results of this treatment are shown by line *D*.

If the weight exceeds 148 lbs. per sq. ft. the concrete cracks and then Mr. Andrews' formulæ have to be applied, but no "increase of strength" can be ascribed to tensile resistance of the concrete.

Neither of these calculations (Mr. Andrews': no tension in concrete; mine: full tension in concrete) takes into consideration the very important fact brought out by the tests (but well known before to German structural engineers) that there is no compression stress in the concrete due to its own weight. According to this result concrete-encased steel joist beams should be calculated like this:

W^1 . . . dead weight of joist and concrete.
W . . . superimposed load.
M^1 . . . section modulus of joist.
B^1 . . . bending moment due to dead weight W^1.
B . . . bending moment due to superimposed load W.

$$\left.\begin{aligned} \therefore\ t_s &= \frac{B^1}{M^1} + \frac{B}{M_T} \\ t_c &= \frac{B}{m \times M_T} \\ c &= \frac{B}{M_C} \end{aligned}\right\}$$

That means in our case:

$$W^1 = 75 \times 5 \times 16 = 6{,}000 \text{ lbs.}$$

$$B^1 = \frac{6{,}000 \times 16 \times 12}{8} = 144{,}000 \text{ in.-lbs.}$$

$$M^1 = 22{\cdot}8 \text{ in.}^3$$

$$\therefore \frac{B^1}{M^1} = 6{,}320 \text{ lbs. per sq. in.}$$

The limit-load which the construction can bear without tensional cracks in the concrete is now 148 lbs. *superimposed* load, or 148 + 75 = 223 lbs. total load.

The stresses are therefore:

Inclusive load $<$ 223 lbs.

$$t_s = 6{,}320 + \frac{B}{55{\cdot}5}$$

$$t_c = \frac{B}{15 \times 55{\cdot}5} = \frac{B}{832{\cdot}5}$$

$$c = \frac{B}{1{,}250}$$

Inclusive load $>$ 223 lbs.

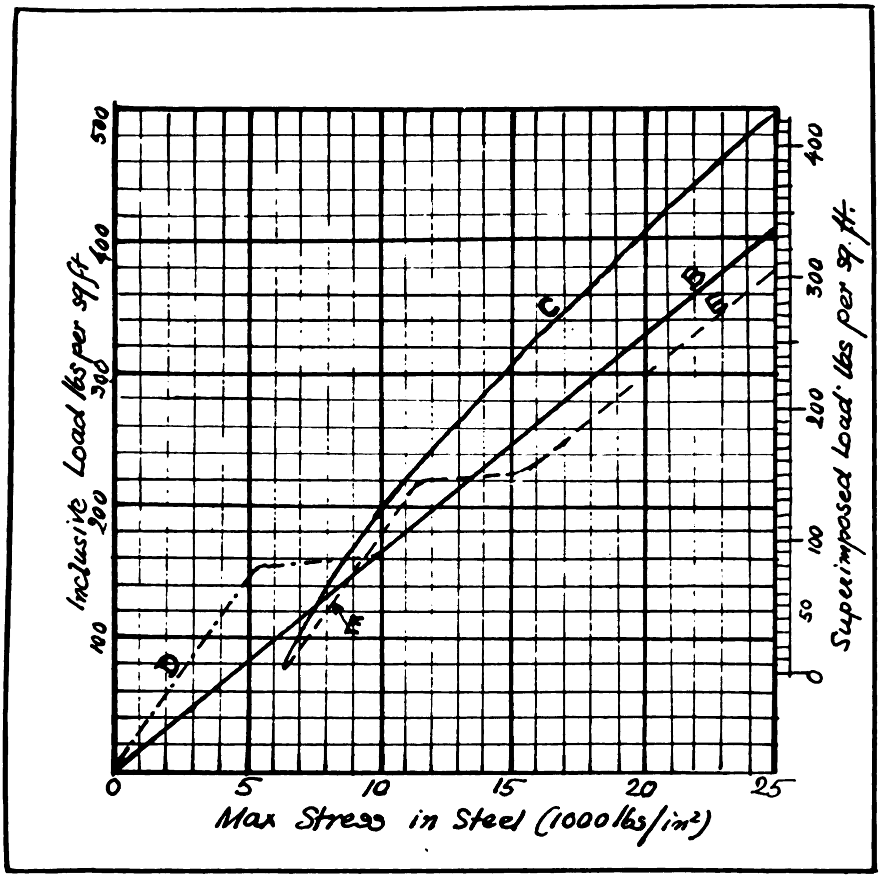
$$t_s = 6{,}320 + \frac{B}{31{\cdot}8}$$

$$t_c = 0$$

$$c = \frac{B}{31{\cdot}8} \times \frac{4}{15 \times 9} = \frac{B}{1{,}073}$$

where *B* is the bending moment due to the superimposed load only.

The results of this treatment are shown by line *E*.



This line runs well-nigh to the test line *C* up to the limit load, but then completely deviates from it. By taking into consideration different moduli of elasticity of concrete for compression and tension, and assuming more correctly a non-rectilinear stress-strain distribution for concrete, it would probably be possible to extend this conformity further, but there will remain for higher loads a discrepancy.

This discrepancy Mr. Andrews has failed to explain, and as far as I can see the record of the tests is quite insufficient to explain it.

Mr. Andrews replies as follows :

Dr. Reiner has raised an interesting point in his letter dealing with my article on the strengthening effect of concrete casing upon structural steelwork.

I do not, however, agree that his letter proves that the tensile resistance of the concrete does not account in part for the excess strength exhibited on test over that given by the ordinary theory for reinforced concrete beams with large section reinforcement. I do not think that concrete in tension can bear a stress of 1,066 lbs. per sq. in., but I do think that the tensile strength of the concrete at a higher level will add to the strength of the composite structure.

Dr. Reiner gives a very interesting treatment on the assumption that there is no compression in the concrete due to its own weight, but this again does not account fully for the test strength developed, as Dr. Reiner's figures show.

In dealing with this matter we have to realise that our theoretical formulæ are based upon certain assumptions which are an approximation to the truth, and that with a composite material like reinforced concrete, having elastic properties which are known to vary in practice, we cannot expect a very close agreement between theoretical and test results.

Dr. Reiner's letter reminds me of the contention raised by M. Considère many years ago that the presence of reinforcement added to the tensile elongation of the concrete before cracking; American tests held that there was no evidence of this, but perhaps the truth may be between the extremes.

CONCRETE MAIN ROAD IN WARWICKSHIRE.

THE length of the concrete section of the Birmingham-Nuneaton main road, illustrated on this page, is approximately 600 yds., the width of the carriageway being 20 ft. The section of road is a diversion carried out to do away with three dangerous corners and to reduce the distance between two points, the length of the old road being about 800 yds.

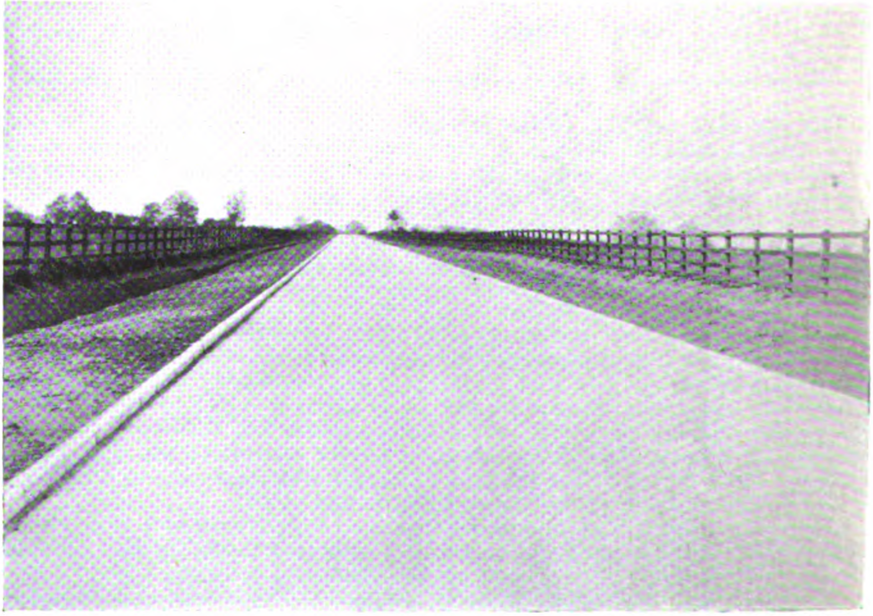
The work was carried out over the full width at one operation and the ground was excavated to an average depth of 12 in. to obtain a regular gradient. The subsoil was gravelly clay and was formed to proper contour, and as the weather was very wet at the time the work was carried out a thickness of about 4 in. of ashes was spread over the whole site and rolled with a horse roller to prevent the clay puddling up through the construction.

The concrete was laid to a depth of 6 in., with one layer of No. 9 B.R.C. fabric 1½ in. from the bottom of the concrete. The work was carried out by direct labour with men who had had no previous experience in this class of work. The concrete was mixed in a concrete mixer (with the minimum amount of water so as to give as dry concrete as possible) in the following proportions: 3 parts washed local granite, 1½ parts washed sand, and 1 part cement.

The concrete was laid by hand and rammed with a heavy camber-staff shaped to the contour of the road and worked by two men, one on each side of the road.

The actual cost of the construction of the concrete road was about 11*s*. 10*d*. per sq. yd.

The work was carried out under the direction of Mr. D. H. Brown, County Surveyor of Warwickshire.



[*Mr. D. H. Brown, County Surveyor.*

CONCRETE MAIN ROAD IN WARWICKSHIRE.

CONCRETE PRODUCTS

CONCRETE ON THE FARM AND ESTATE.

We give below abstracts from the essay by Mr. J. S. Bray, which was awarded first prize in Section B in the essay competition recently promoted by the Concrete Utilities Bureau :—

The advantages of concrete over other materials may be summarised as follows :

(*a*) Durability, either in blocks, mass form, or reinforced with steel bars.

(*b*) Easy and simple form of construction.

(*c*) Strength.

(*d*) Fire resisting.

(*e*) Cheapness in the long run.

(*f*) No maintenance cost after the first outlay.

(*g*) Impermeability and cleanliness.

Further it is a home product, and its general use would give work to British workmen and to a certain extent relieve the unemployment question.

GATE POSTS AND FENCES.

On many estates at the present time there is a shortage of timber gate posts, and even if there were not it is much preferable to have concrete posts. A mould in which they may be cast is very easily constructed, and when once made it is a simple matter to make up a few dozen posts for future use.

The posts should be made and fixed as shown in *Fig.* 1. A hole should be made at *a* for the gate fastener. At *b* and *c* holes should be made through the posts for gate crooks. The reason for the projections *d*, *d* is to prevent carts and heavy vehicles from striking the post. Without this I have found in practice that the wheel of a very heavy vehicle striking suddenly is liable to fracture the concrete.

A suitable size for hanging and falling posts is 9 in. by 9 in. and 6 in. by 6 in. respectively.

Where the hedges are turfed behind the posts it is advisable to leave four slots in the back of the posts and mould out four rails 3 in. by 2 in. from 3 to 5 ft. long and placed as shown in *Fig.* 1. Where there is a stone hedge behind this is unnecessary. In the western counties, where there are many turf banks, it is very necessary as it is always difficult to keep a fence behind posts. Some surveyors recommend reinforcement with rods for the posts, but I consider this unnecessary for the sizes suggested.

FENCES.

The posts for these are better made tapering 6 in. by 6 in. at the bottom and tapering to 4 in. by 4 in. on the top. They should not be of smaller dimensions, for in some cases where made smaller I have noticed they are liable to break near the ground on account of cattle rubbing against them, or a sudden blow.

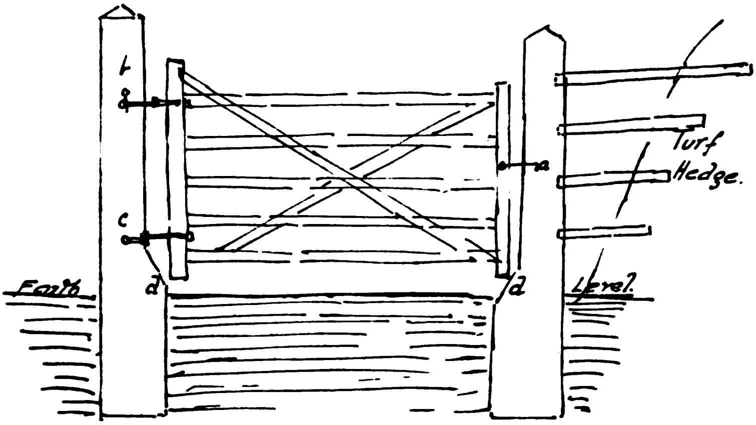
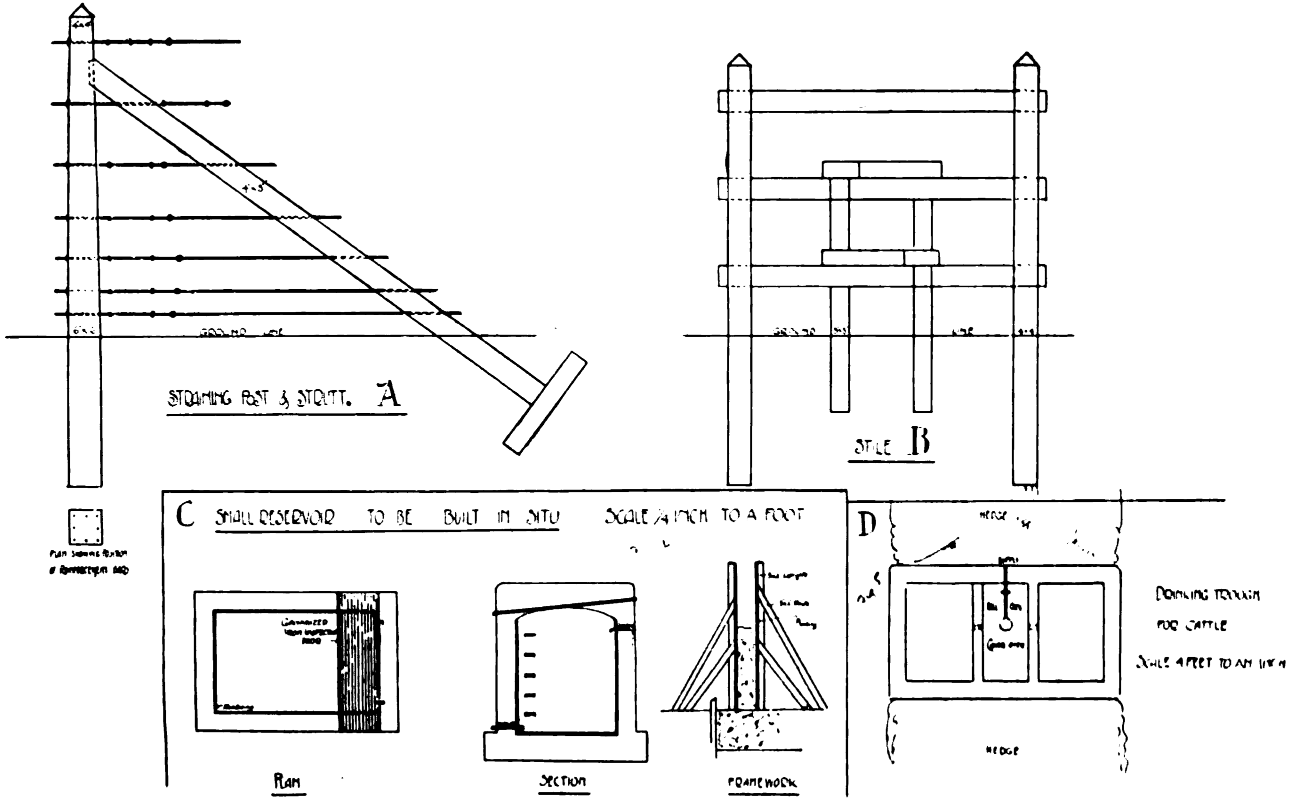


Fig. 1.


STRAINING POST & STRUTT. A
4-3"
GROUND LINE
PLAN SHOWING POSITION OF REINFORCING ROD
STILE B
GROUND LINE
C SMALL RESERVOIR TO BE BUILT IN SITU
SCALE ¼ INCH TO A FOOT
GALVANIZED IRON INSPECTION ROD
PLAN
SECTION
FRAMEWORK
D
HEDGE
HEDGE
DRINKING TROUGH
FOR CATTLE
SCALE 4 FEET TO AN INCH

DRAWING No. 1.

For straining posts reinforcement is recommended, and steel rods ¾-in. diameter are suitable for this; eight in each post are sufficient for all practical purposes, placed where shown in Drawing 1*a*. Struts should be placed where the strain is excessive, and made as shown.

STILES.

Stiles may be constructed as shown in Drawing 1*b*.

RESERVOIRS.

There is no better material for reservoir construction than concrete rendered inside with cement mortar. The design shown in Drawing 1*c* is recommended, and can easily be moulded and built *in situ*.

DRINKING TROUGHS.

In most cases several troughs are required, and it is advisable to get the mould made for a convenient and practical size and then turn out what is necessary. Generally speaking, one trough will supply two fields and a useful plan to adopt is that shown in Drawing 1*d*. These troughs should be rendered inside in cement. Troughs fixed in yards need only one drinking place and a chamber for the ball-cock.

BRIDGES OVER CULVERTS, ETC.

These can be easily constructed, and they are everlasting. They may be made as shown in Drawing 2*a*. They should be reinforced at right angles, otherwise the wheels of heavy traffic might come where there is no reinforcement and cause a fracture.

CHANNELS FOR WATER.

Channels may be constructed as shown in Drawing 2*a*, and if a top is required a concrete slab may easily be fixed.

WELLS.

Most wells for drinking-water require steining, and concrete slabs are very suitable for this, placed as shown in Drawing 2*b* and set in cement. In practice it is not often necessary to stein more than about 6 to 10 ft. from the top.

RAM ENCLOSURES.

Concrete is an excellent material for this purpose, owing to the surroundings always being wet. It is difficult to show by drawings how it can be placed, as the circumstances will depend on each individual case, but I show on Drawing 2*c* a ram enclosure on a property in which I am interested; it is very simple in construction and can be laid *in situ*.

AGRICULTURAL ROLLERS.

Concrete for agricultural rollers does not seem to be very general at the present time, but I see no reason why it could not be utilised for this purpose. They could be made a plain round or they could be made Cambridge pattern or fluted lengthways; the two latter are more suitable as clot crushers. Reinforcement with steel bars would be necessary, and the centre bar could be continued to form an axle for the framing.

BEDS FOR ENGINES.

Engines which have to be fixed on a solid foundation should be set on concrete blocks, which can easily be adapted to fit any particular case.

STANDARDS FOR WATER WHEELS.

Here again, where the surroundings are always damp, it is necessary to have a non-perishable material. These standards can always be built *in situ*, and a good method is shown in Drawing 2*d*. The launder should also be of concrete.

BASES FOR WINDMILLS.

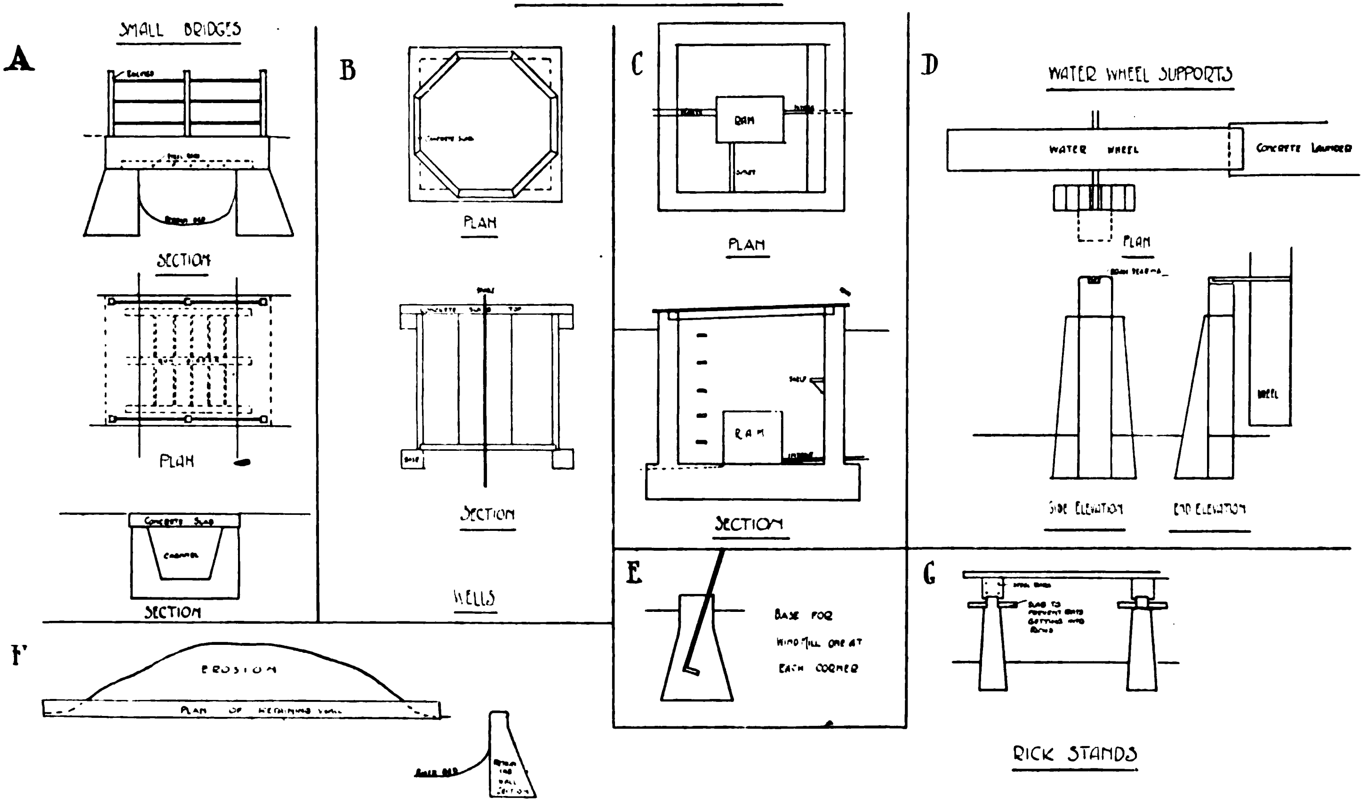
Concrete blocks are the only satisfactory base for a windmill, and I am specifying at the present time blocks as shown on Drawing 2*d* for this purpose.

DAMS.

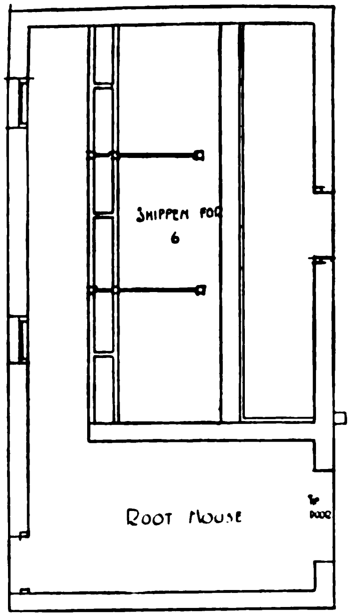
It is often necessary to prevent the erosion of rivers, and in this case nothing more suitable can be devised than concrete. Each particular case requires different treatment, but the broad principles are the same, and on Drawing 2*f* I give a sketch of a case I have in hand at the present time.

MANURE AND INSPECTION PITS.

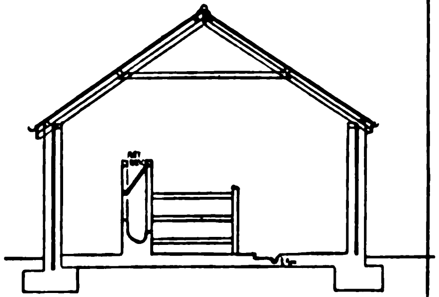
These can easily be constructed of concrete. After the excavations have been carried out the concrete sides can be built up on the floor by placing boards to form the moulds and filling in with concrete. Some recommend a concrete cover, but in practice I prefer a concrete arch over one half and a trap door over the other half. My reason for this is that I have not found the manure pumps very satisfactory, and I consider a better


A
SMALL BRIDGES
SECTION
PLAN
CONCRETE SLAB
CHANNEL
SECTION
B
PLAN
SECTION
WELLS
C
RAM
PLAN
SHELF
RAM
SECTION
D
WATER WHEEL SUPPORTS
WATER WHEEL
CONCRETE LAUNDER
PLAN
WHEEL
SIDE ELEVATION
END ELEVATION
E
BASE FOR
WIND MILL ONE AT
EACH CORNER
F
EROSION
PLAN OF RETAINING WALL
G
SLAB TO
PREVENT RATS
GETTING INTO
RICKS
RICK STANDS

Drawing No. 2.

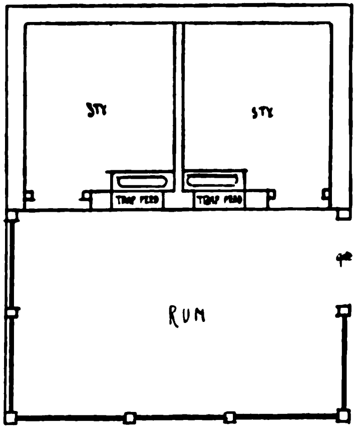


PLAN FOR SMALL SHIPPEN



SECTION

SCALE 4 FEET TO AN INCH



SMALL PIGSTY

DRAWING NO. 3.

way of cleaning out the chamber is to remove the trap door and pump the liquid into a suitable conveyance. Inspection pits can be made in the same way, but the bottoms should be rendered around the half-pipes.

MOW AND RICK STANDS.

On account of destruction by rats it is always advisable to get the ricks of corn off the ground. Drawing 2*g* shows a method of making a suitable stand.

FARM BUILDINGS.

Modern science has taught us the importance of sanitation and cleanliness both for man and beast. Agricultural science and legislation have endeavoured to improve the standard, but with unsuitable and old buildings cleanliness is practically impossible. No material lends itself more to good sanitation and cleanliness than concrete, and a model up-to-date farm will in the near future have its dwelling-house, cottages, barns, shippens, stables, piggeries, implement sheds, cattle sheds, drinking troughs, manure pits and silos all built of concrete.

I am convinced that when the landed proprietor realises the simplicity with which concrete can be handled, its durability and limited cost of upkeep, its use will become much more general. One has only to travel over some of our railways to-day to see that concrete is being used for nearly all constructional purposes.

OUTBUILDINGS.

The best type of block for outbuildings is the hollow type, 18 in. by 9 in. by 9 in. plain faced. These can easily be handled and openings for bearings for pulleys and supports for roof principals can be arranged where required and given extra strength. Solid work is desirable.

In moulding these blocks it is advisable in order to minimise the porosity that the facing should be of a rich mixture, say 1 of cement to 2 sand, about ¾ in. thick. This can easily be done by placing it in the mould at the bottom, pressing upon it a backing of ordinary concrete.

SHIPPENS.

Drawing 3*a* shows a section through a cow shippen. Based on years of practical experience I consider the gutter shown to be the most useful and sanitary.

PIGGERY.

Cement is an excellent material for this purpose, and Drawing 3*b* shows a useful plan for a two-sty piggery.

CONCRETE GATE POSTS IN IRELAND.

CONCRETE VERSUS BRICK FOR COTTAGE CONSTRUCTION.

A RECENT issue of the *Journal* of the Institution of Municipal and County Engineers contains a report by Mr. F. Thackeray, Borough Architect of Merthyr Tydfil, on the replies received to a questionnaire on the subject of the use of concrete for house building, from which we take the following :—

" The weight of evidence is in favour of using concrete where suitable aggregate can be locally obtained, if good common bricks are high in price, of uncertain or insufficient delivery, and if bricklayers are scarce. Proper concrete construction requires more skilled supervision than brickwork—i.e. the skilled workmen on concrete work require to be more highly skilled than the skilled workmen on brickwork, but on concrete work the skilled men can be fewer in number and the unskilled can be more than for brickwork, if manual labour is intended to be used to full extent.

" Machinery can enter more fully in building operations by concrete than by brickwork, resulting in more labour saving and rapid progress. Some state they have built concrete houses without any skilled labour.

" One public authority engineer states that he does not intend to build any more brick houses, and is just making arrangements for 500 concrete houses, and claims fifteen years' experience with concrete houses.

" Two replies came from contractors for ordinary building works (not concrete specialists), one of them very well known to the writer, as he has executed contracts for scores of thousands of pounds worth of brickwork from his plans. Both replies are from the firms they represent, and state thus : ' Taking into account the shortage of bricks and bricklayers all over the country, we are of opinion that unless concrete houses are erected the housing question will never be solved.' The second reply, from a place over 200 miles away from the first, says : ' I have built a large number of houses with concrete construction, and where you have a suitable aggregate it is cheaper to build with concrete than with bricks. There is nothing whatever, so far as I know, against its use. I feel certain, if the housing question is to be coped with, this is the only way out of it.'

" Another firm of general contractors in a large way of business say : ' We have had considerable experience in the matter of concrete houses, and have erected over 400 in various places. There are special difficulties to overcome and conditions that must be complied with in dealing with this material. We find that a great deal of prejudice exists on this account in the minds of employers and operatives in the building industry, but it would be unwise to ignore the use of concrete in existing circumstances.'

" A Housing Director who has built thousands of houses of brick and thousands of concrete says : ' My experience is that where suitable aggregate exists for concrete and the right type of concrete is used a house built of this material is just as sound as a house built of brick walls.'

" One authority has built 204 concrete houses ; the tenants are so pleased with them that a great number of the tenants have purchased them. The Surveyor of another authority says : ' Built 62 houses of brick and 100 houses of concrete ; the concrete houses were a little cheaper than brick, and are by far the strongest on the estate.' Another Borough Surveyor writes : ' My Corporation has erected concrete houses which have proved satisfactory in every respect from a constructional point of view. There is, of course, a great prejudice against this form of construction amongst some of the members of the committee, and it is undoubtedly increased by the local builders. The tenants themselves are almost without exception quite satisfied with the premises, the houses are perfectly dry, and I have not had any more complaints from the tenants of these houses than have been received from a corresponding number of occupants of brick houses.'

" A firm of contractors who have built 5,000 houses, brick and concrete, during the past four years say : ' Concrete houses are perfectly satisfactory. They can be built entirely without bricklayers ; they will cost less for maintenance.' Another large firm of general contractors (not concrete specialists) say : ' There is no reason whatever why suitable concrete houses should not be built. We have erected, approximately, 100 in all parts of the country. We find that where concrete houses are built, especially when the outsides are rendered, they answer admirably.' The Executive Housing Officer of a city where thousands of houses of all kinds have been built and where several thousands of concrete houses are in progress, says: 'As we cannot get anything approaching sufficient houses built in brickwork, owing to the want of bricklayers, the Corporation have no alternative but to build concrete houses, and from what they have seen of them they are satisfied they will get good results.'

"Some correspondents point out the difficulties placed in the way of house building by concrete by bricklayers claiming the work, and not effecting the economies of time possible by some concrete methods over brickwork. Two firms of specialist concrete house builders have informed me that bricklayers' unions in the Midlands do not now put any objections in the way of their pre-cast concrete block system.

"Concrete house building proposals have sometimes led to disappointments, caused by exaggerated claims of economy made by too sanguine advocates of concrete as against brick. On the other hand, it may be said that concrete house building proposals have suffered undue criticism due to the rooted objection of the British people to anything new. Not that concrete construction is new, but the idea of having houses built of concrete instead of brick or stone is comparatively new. In some cases the claims of concrete have been over-stated and in others the claims have not had due consideration.

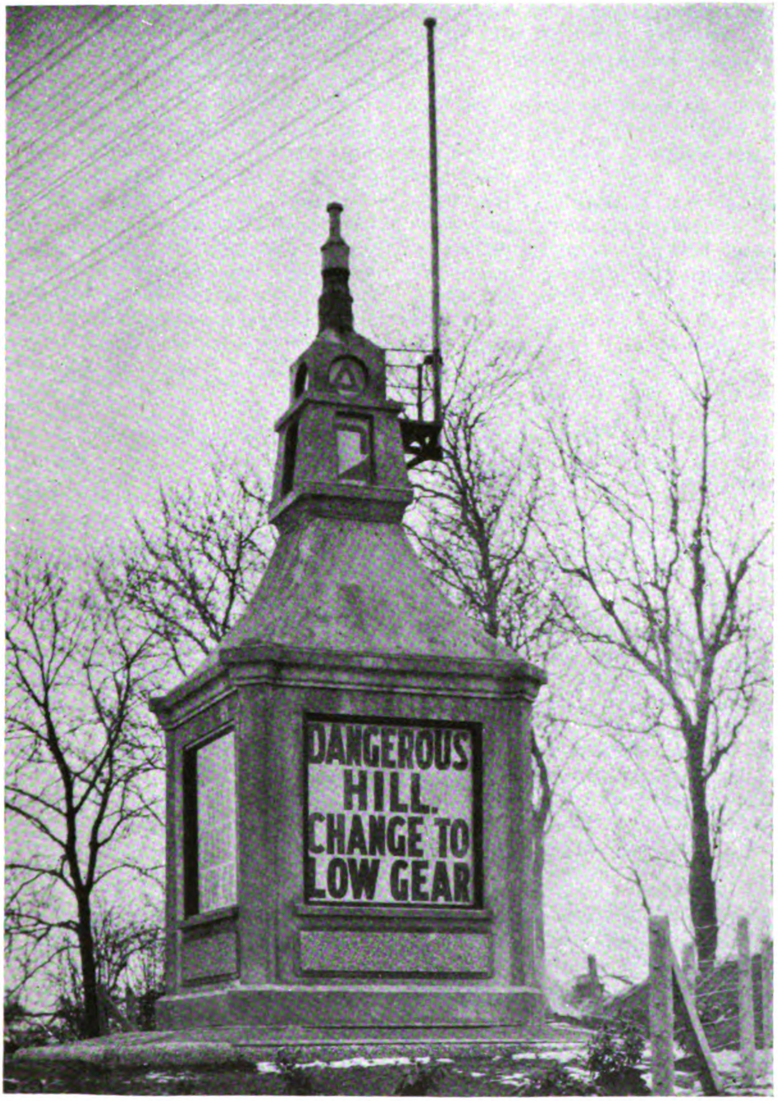
"If this condensed review of the answers to my questionnaire assists in removing some of the misunderstandings, I venture to say that all the gentlemen who so kindly gave their views will feel they have done something towards ascertaining the true position and may stimulate thought in many directions as to the best methods of solving the great national problem of housing on sound economical lines by not being compelled to build on any one method, but having the choice of several alternatives.

"An economic problem of the nation calls forth economic theories for its solution. The greatest economiser of human labour is machinery. In the building of houses by ordinary methods human labour takes up a very large share. If some of that labour can be done by machinery the man-power of the building industry can be utilised for greater numbers of houses, and houses may be built more quickly and cheaply than at present.

"It appears to me that concrete methods of building lend themselves more than brick methods do for adaptation by machinery. Elaborate machinery is used for brick-making on a large scale. Concrete can not only be better made by machinery than by hand; it can be raised to its required position, poured, moulded or tamped by mechanical processes, with motive power of steam, electricity or petrol, thereby saving human labour and reducing the cost of building as well as accelerating the output of the work. This would provide more work for labourers in preparing more sites for more houses and preparing the raw materials for the building schemes."

Architects' and Surveyors' Assistants' Professional Union.

THE address of the Architects' and Surveyors' Assistants' Professional Union has been changed from 36, Victoria Street, S.W.1, to 26, Buckingham Gate, Westminster, S.W.1.



CONCRETE ROAD LIGHTHOUSE AT CONGLETON. (*See p.* 468.)

CONCRETE ROAD LIGHTHOUSE.

THE concrete lighthouse illustrated on p. 467 has been built for the illumination of Rood Hill, Congleton. The structure, 28 ft. in height, is situated at a bend where the roadway has been increased from 22 ft. to 75 ft. in width, and lights up after dark the entire length of the hill.

The lower part of the tower has two windows, 6 ft. square, fitted with signs bearing the words: "Dangerous hill: Change to low gear," these warnings being illuminated at night by incandescent gas burners of 2,000 candle-power. The interior contains a room placed at the disposal of the Royal Automobile Club for the use of motorists, and fitted with a gas stove and wash basin, the latter having hot and cold water supplies.

In the upper part of the tower are rectangular and circular openings with conventional warnings, all being illuminated after dark, and on the summit there is a revolving lantern throwing powerful alternating beams of red and green light up and down the hill, these lights being visible for a distance of seven miles in clear weather.

The work, begun in 1922, has given employment to many Congleton men who were out of work. The Borough bore 25 per cent. of the cost, the Ministry of Transport contributing 50 per cent. and the Cheshire County Council 25 per cent.

The Borough Surveyor is Mr. P. A. Watford, and the structure was built on the Mouchel-Hennebique system by the Yorkshire Hennebique Contracting Co., Ltd., with cement supplied by Messrs. G. and I. W. Carter, of Lawton Street, Congleton.

NEW CONCRETE HOUSING SCHEMES.

A SCHEME for the erection of 193 concrete houses is under consideration by the Housing Committee of the Birkenhead Corporation. It is proposed to erect these houses on a site at Rock Ferry.

After considering the merits of various materials for the erection of its housing scheme, the Housing Committee at Bristol has recommended the Town Council to construct 300 concrete houses.

The Corporation of Carlisle, which has been considering the erection of concrete bungalows for some time, has now proceeded a step farther and applied for a loan to erect 50 bungalows in concrete, at a cost of about £333 each.

A scheme for the erection of concrete cottages is being considered by the Town Council of Kirriemuir.

A considerable amount of discussion on concrete versus brick for cottage construction has recently been held in Leicester, and the Housing Committee has inspected the concrete housing scheme at Liverpool with a view to erecting similar houses at Leicester.

OTHER HOUSING SCHEMES.

Among other housing schemes now under consideration, further particulars of which are given elsewhere in this issue under the heading "Prospective New Concrete Work," are the following:—

Merthyr Tydfil (78 houses).
Altrincham (100 houses).
Benfieldside (40 houses).
Bentley (350 houses).
Blackwell (40 houses).
Bolton (250 houses).
Hendon (88 houses).
Lanark (£150,000 scheme).
Orsett (100 houses).
Eastbourne (62 houses).
Bolsover Colliery Co., Ltd. (956 houses).
Exmouth (200 houses).
Great Yarmouth (48 houses).
Kidwelly (50 houses).
Stafford (100 houses).
Liverpool (6,000 houses).
Paisley (100 houses).
Perth (£25,000 scheme).
Renfrew (60 houses).
Stanley (144 houses).
Stretford (50 houses).
Taunton (100 houses).
Willington (60 houses).
Wombwell (60 houses.)

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	„	14	0
„ „ ½ in. mesh	„	15	0
Best British Portland Cement	per ton 58*s.* to	63	0
"Ferrocrete" Portland Cement	10*s.* per ton extra		

Boarding for Shuttering—

		Sawn. s.	*Sawn.* d.	*Wrot.* s.	*Wrot.* d.
1 in.	per square	23	6	27	6
1¼ in.	„	29	6	33	6
1½ in.	„	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £24 10*s.* per standard
3 in. by 6 in. and 3 in. by 7 in.	„ £25 10*s.* „ „

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
9/16 in. to ½ in. Rounds	„	13	6
⅜ in. Rounds	„	14	6
¼ in. Rounds	„	15	6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(*Based on Contracts up to £2,000.*)

Portland Cement Concrete well mixed with Clean Water in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per yard cube	45	6
Do.	do.	in columns	„ „	50	6
Do.	do.	in beams	„ „	50	6
Do.	do.	in floor slabs 4 in. thick	per yard super	5	4
Do.	do.	in floor slabs 6 in. thick	„ „	7	11
Do.	do.	in floor slabs 9 in. thick	„ „	11	6
Do.	do.	in walls 6 in. thick	„ „	8	2

(*Add for hoisting 3s. 6d. per yard cube above ground-floor level.*)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	24	0
„ 9/16 in. to ½ in.	„	23	0
„ ⅝ in. to 2⅞ in.	„	22	0

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.*

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.*

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	55	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	51	0
Do. do. in small quantities	per ft. super	0	9½
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last, in narrow widths	„ „	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	„ „	1	1
Do. do. as last, in narrow widths	„ „	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	„ „	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are those current in the London area, namely:—Carpenters and joiners, 1/8 per hour; Labourers on building works, 1/3; Operators on concrete mixers and hoists, 1/4.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

PROSPECTIVE NEW CONCRETE WORK.

ABERFAN. — *Houses.* — The Merthyr Tydfil T.C. has applied for a loan of £40,000 for the construction of 78 houses.

ALTRINCHAM.—*Houses.*—The T.C. has under consideration a scheme for the construction of 100 houses.

BANSTEAD.—*Sewage Works.*—The Epsom R.D.C. has applied to the M.H. for sanction to borrow £21,142 for the construction of sewage disposal works at Cheam.

BARMOUTH. — *Sea Defences.* — The U.D.C. has applied to the M.H. for sanction to borrow £18,000 in connection with the plans for sea defence works which will include the construction of ten groynes.

BENFIELDSIDE.—*Houses.*—The U.D.C. proposes to erect 40 houses.

BENTLEY.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to purchase land in connection with the construction of 350 houses.

BIDEFORD.—*Road.*—The T.C. is considering the construction of a road between Bideford and Northam Road.

BIRKENHEAD.—*Concrete Houses.*—The Corporation has under consideration a scheme for the construction of 193 concrete houses at Rock Ferry.

BLACKWELL. — *Houses.* — The R.D.C. proposes to construct 40 houses.

BOLTON.—*Houses.*—The Corporation has under consideration the construction of 250 houses.

BRENT.—*Houses.*—The Hendon R.D.C. has submitted to the M.H. a scheme for the construction of 88 houses, estimated to cost £47,000.

BRISTOL.—*Concrete Houses.*—The Corporation Housing Committee recommends the construction of 300 concrete houses.

CARFIN.—*Houses.*—The Housing Committee of the Middle Ward of Lanark proposes to erect houses at Carfin, Holytown, Bargeddie, and Kingshill, at an estimated cost of £150,000.

CARLISLE.—*Concrete Bungalows.*—The Corporation has applied for assistance for the construction of 50 concrete bungalows, estimated to cost about £333 each.

CORRINGHAM. — *Houses.* — The Orsett R.D.C. has applied to the M.H. for sanction to errect 100 houses.

DOUGLAS. — *Culvert.* — The T.C. has agreed to the construction of a concrete culvert for the stream at Peel Road, at an estimated cost of £300.

EASTBOURNE.—*Houses.*—The T.C. proposes to construct 62 houses by direct labour.

EDWINSTONE.—*Houses.*—The Bolsover Colliery Co., Ltd., have submitted a scheme to the Notts C.C. for the construction of 956 houses.

EXMOUTH.—*Houses.*—The U.D.C. is negotiating for the purchase of land in connection with the construction of 200 houses.

GREAT YARMOUTH.—*Houses.*—The Corporation proposes to erect 48 houses at a cost of £369 each.

GRIMSBY.—*Concrete Road.*—The T.C. proposes to construct Laceby Road with reinforced concrete, at an estimated cost of £43,000.

HOLBORN (LONDON). — *Houses.* — The B.C. has under consideration a scheme for the construction of 81 houses at an estimated cost of £54,250.

KELLS.—*Road.*—The Whitehaven T.C. proposes to construct a road to Kells, at an estimated cost of £11,000.

KIDWELLY.—*Houses.*—The T.C. has applied to the M.H. for sanction to erect 50 houses.

KIRRIEMUIR.—*Concrete Houses.*—The T.C. is considering a scheme for the construction of concrete houses.

LAMMASCOTE.—*Houses.*—The Housing Committee of the Stafford T.C. proposes to erect 100 houses.

LEICESTER.—*Bridges.*—The T.C. proposes to construct two bridges across the Saffron Brook.

LEICESTER.—*Concrete Houses.*—A deputation of the Housing Committee has paid a visit to the concrete houses at Liverpool with a view to embarking upon a scheme for the construction of concrete houses at Leicester.

LIVERPOOL.—*Houses.*—The Corporation Housing Committee has approved the site for the construction of 6,000 or 7,000 houses.

LLANDOVERY.—*Road.*—The T.C. has applied to the M.T. for a grant towards the construction of a road near College View.

MERTHYR TYDFIL.—*Bridge.*—The T.C. has applied to the M.T. for sanction to borrow £11,000 for the construction of a ferro-concrete bridge.

Paisley.—*Houses.*—The T.C. proposes to erect 100 houses.

Perth.—*Houses.*—The T.C. has applied to the M.H. for sanction to borrow £25,000 for the erection of houses at Dunkeld Road.

Renfrew.—*Houses.*—The T.C. has secured a site for the erection of 60 houses.

Saltburn. — *Sewage Works.* — The U.D.C. has applied to the M.H. for sanction to borrow £19,000 for sewage disposal works.

Stanley.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to erect 144 houses.

Stretford. — *Houses.* — The U.D.C. has applied to the M.H. for sanction to erect 50 houses on the Seymour Grove estate.

Taunton.—*Houses.*—The T.C. has a scheme on hand for the construction of 100 houses on the Lambrook Farm estate.

Whitecrook. — *Bridge.* — The Clydebank T.C. has under consideration a scheme for the construction of a bridge over the canal and a culvert underneath at Whitecrook, at an estimated cost of £17,000.

Willington. — *Houses.* — The U.D.C. proposes to construct 60 houses.

Wombwell.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to erect 60 houses on the King's Road site.

TENDERS ACCEPTED.

Adel (near Leeds).—*Sewage Disposal Works.*—The Wharfedale R.D.C. has accepted the tender of Mr. J. E. Waterhouse, Leeds, at £3,700, for the construction of a new sewage scheme.

Antrim.—*Concrete Roads.*—The C.C. has accepted the tender of Messrs. F. B. McKee & Co., Ltd., Shore Road, Belfast, for the construction of concrete roads.

Baslow. — *Bridge.* — The Derbyshire C.C. has accepted the tender of Messrs. R. Lehane & Co., Ltd., Darley Dale, at £21,000, for the construction of a concrete bridge.

Bournemouth.—*Foot Bridges.*—The T.C. has accepted the tenders of Messrs. F. Bevis, Ltd., at £1,678 and £1,651 15*s.*, for the construction of reinforced concrete bridges at the Boscombe Chine and Alum Chine Gardens.

Bradford.—*Concrete Houses.*— The Corporation has accepted the tenders of Messrs. Henry Boot & Sons (London), Ltd., for the construction of 116 concrete houses at £516 each, and 500 concrete houses at £415 each.

Chorley.—*Sewage Works.*—The T.C. has accepted the tender of Messrs. Baxendale Bros. (Chorley), Ltd., at £40,670, for the construction of sewage disposal works.

Felstead (Essex).—*Sewage Works.*—The Dunmow R.D.C. has accepted the tender of Mr. H. H. Barry, Radcliffe-on-Trent, at £1,144, for the construction of sewage disposal works for the parish of Felstead.

Furnace End.—*Bridge.*—The Warwickshire C.C. has accepted the tender of the Reinforced Concrete Construction Co., at £1,571, for improvement to the bridge at Furnace End.

Guildford.—*Concrete Road.*—The T.C. has accepted the tender of Mr. J. Douglas, Southampton, at £1,871, for the construction of a concrete road in Onslow Street.

Honiton.—*Sewage Disposal Works.*—The T.C. has accepted the tender of Mr. M. Vine, Bournemouth, at £11,890 11*s.*, for the construction of sewage disposal works.

Hornsey. — *Playground.* — The Middlesex C.C. has accepted the tender of Messrs. Leslie & Co., at £1,225, for the erection of a ferro-concrete wall, steps, and railings in connection with the reconstruction of the playground at Stationers' School, Hornsey.

Isle of Ely.—*Bridge.*—The C.C. has accepted the tender of Messrs. Baldry, Yerburgh & Hutchinson, Ltd., at £6,918, for the construction of a ferro-concrete bridge.

Long Eaton.—*Sewage Works.*—The U.D.C. has accepted the tender of Messrs. Ward & Tetley, at £22,500, for the construction of sewage works.

Manchester. — *Building.* — The Corporation has accepted the tender of Messrs. J. Gerrard & Sons (1920), Ltd., for the construction of a reinforced concrete building, pipe laying, etc.

Monifieth.—*Channelling.*—The T.C. has accepted the tender of Mr. C. Dick, Monifieth, at £481 3*s.* 9*d.*, for concrete channelling and gullying at the Milton extension scheme.

NEWTON ABBOT.—*Resurfacing.*—The U.D.C. has accepted the tender of Messrs. F. J. Lealley & Son, Newton Abbot, at £1,325, for resurfacing a portion of the Market Square with reinforced concrete.

POLESWORTH.—*Bridge.*—The Warwickshire C.C. has accepted the tender of the Reinforced Concrete Construction Co., Manchester, at £5,443, for improvement of the bridge at Polesworth.

SMETHWICK.—*Bridge.*—The T.C. has accepted the tender of Messrs. Gray's Ferro-Concrete Co., Ltd., Glasgow, at £5,367, for the reconstruction of Rolfe Bridge.

SPENNYMORE.—*Flags.*—The Durham C.C. has accepted the tender of the Stockton Stone & Concrete Co., at £165, for the supply of 600 2¼-in. concrete flags.

SWANSEA. — *Bridge.* — The Swansea R.D.C. has accepted the tender of Messrs. J. E. Jones & Co., at £3,247 10*s.*, for the construction of a new ferro-concrete bridge over the River Lliw at Gorseinon.

TYDD ST. GILES (LINCS).—*Bridge.*—The Isle of Ely C.C. has accepted the tender of the Yorkshire Hennebique Contracting Co., at £2,508, for the construction of a ferro-concrete bridge over the Old Shire Drain.

WEALDSTONE.—*Culvert.*—The U.D.C. has accepted the tender of Mr. H. Pickrill, Wealdstone, at £3,070, for the construction of a concrete culvert.

WHITSTABLE. — *Culverts, etc.* — The U.D.C. has accepted the tender of The Warwickshire Bridge & Engineering Co., Leamington, at £5,317, for the construction of reinforced concrete culverts along the stream dyke, and all works in connection thereto.

Pre-Cast Concrete in Maritime Works.

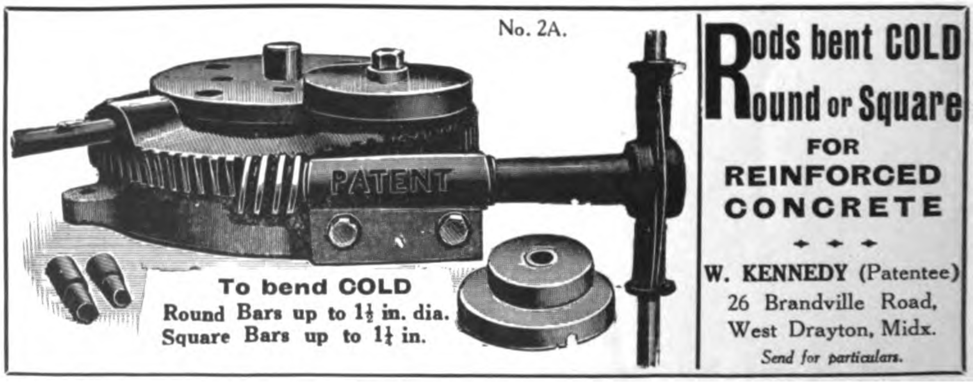
IN the account of the interesting concrete work carried out at Bremerton (U.S.A.) Navy Yard, given in our issue for May under this heading, we omitted to state that Mr. Wm. F. Way was the designing engineer and Messrs. Henry & McFee the contractors.

TRADE NOTICES.

The Bristol office of The British Reinforced Concrete Engineering Co., Ltd., is now at Sun Buildings, Clare Street. Telephone: Bristol 5544; Telegrams: British Reinforced, Sun Buildings, Bristol.

The firm of Winget, Limited, has been reconstructed under the title of Winget (1924), Ltd. Mr. J. Faulder Burn, the founder of the firm, remains Chairman and Managing Director of the new Company.

The telegraphic address of Messrs. Chimneys, Limited (47, Victoria Street, London, S.W.1) has been changed to "STABLOCHIM, SOWEST, LONDON." The telephone number remains as before, Victoria 4700.



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AUGUST 1924 VOL. XIX. No. 8

A MONTHLY JOURNAL for Engineers, Architects, Surveyors and Contractors and all interested in Cement, Concrete, Reinforced Concrete, Fire-Resisting Construction and Structural Steel.

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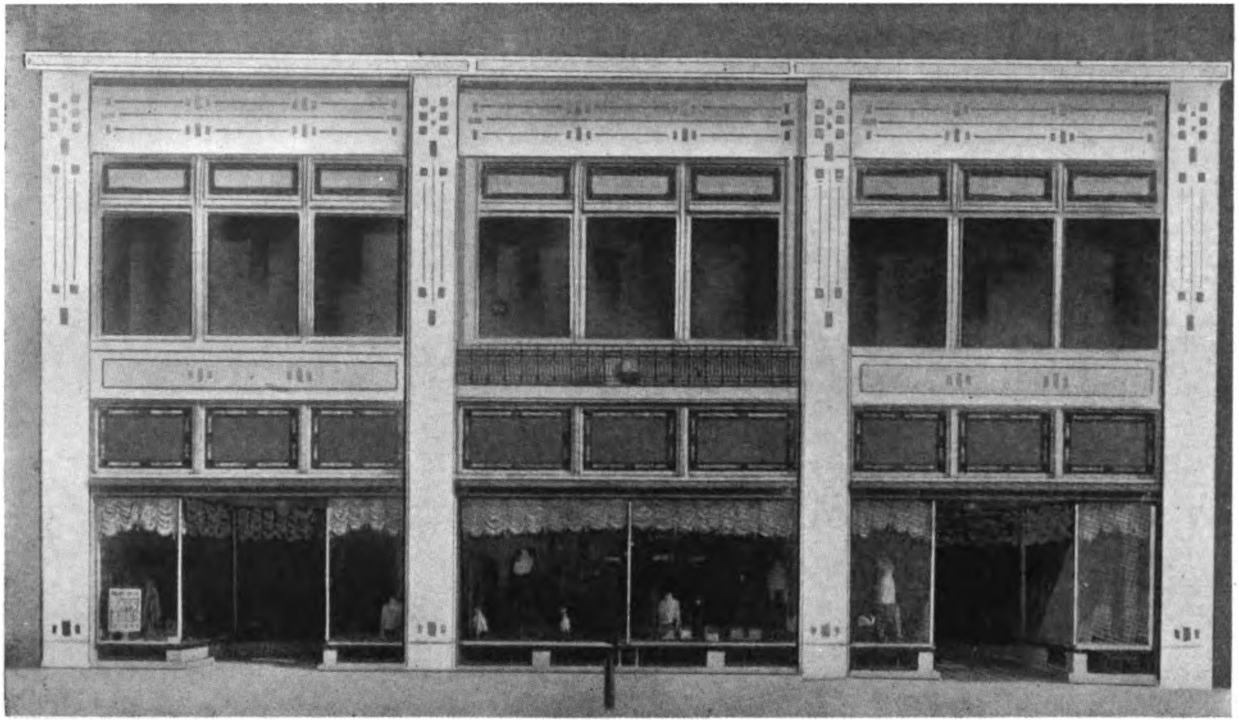

FIG. 9.—SHOP FRONT IN REINFORCED CONCRETE: DECORATED WITH COLOURED CONCRETE TILES AND PAINT.

EXTERIOR TREATMENT OF CONCRETE BUILDINGS.

(*See page* 481.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIX. No 8 LONDON, AUGUST, 1924

EDITORIAL NOTES.

THE FACTOR OF SAFETY.

THE term " factor of safety " is one of those convenient expressions which sound scientific and have a curious fascination for those people who are on the borderland of structural engineering and who like to be considered as within its pale. If it meant anything quite definite it would be a most valuable expression, but as it is used in several different senses by different people it is well to remind ourselves of certain aspects of its use which are of particular importance to reinforced concrete construction.

In ordinary structural work we speak of designing upon a factor of safety of four. By this we mean that the working stress that we adopt in the design is one-quarter of the ultimate strength of the material. This does not mean that if we tested our structure to destruction the load required to cause failure would be four times that which the structure actually has to carry. The reasons why these two things are not the same depend upon many factors, the most important of which is the existence of the property known as the " yield point " in ductile materials. The formulæ which are employed in the design of all structures using steel are based upon certain assumptions, one of which is that the material is elastic, and this assumption no longer holds after the yield point has been passed.

Many engineers, particularly those who delight in labelling themselves as practical men, use the term " factor of safety " as having the second meaning referred to above ; that is, the result of dividing the failure load by the design load, as if the failure load were an easy thing to forecast. It would save a great deal of loose thinking and wild statement if we could adopt a new phrase such as " load test factor " to express this quantity. Unfortunately we are unable to carry out the advice of the Hibernian gentleman who expressed the opinion that every structure should be tested to destruction before it is allowed to be used.

Experimental investigations are constantly being made upon the relation between failure loads and design loads of various structures and structural elements, and from the results of these investigations we modify our formulæ from time to time ; we should always be striving to find formulæ which express the experimental facts instead of regarding old formulæ as sacred or adopting the attitude that all formulæ are useless. Although it is true that occasionally we come across cases in which the load test factor of a structure is considerably in excess of 4, it is more often less than 4, a very common figure being just over 3 and for most cases this is all that is required in practice.

We may here draw attention to an important consideration in connection with reinforced concrete floors, and will illustrate the matter by a numerical example. Suppose we have a reinforced concrete floor weighing 60 lbs. per sq. ft. which is designed for a superimposed load of 84 lbs. per sq. ft., thus giving a design or inclusive load of 144 lbs. per sq. ft. The question is, "What ultimate or failure load on this floor will correspond to a load test factor of four ?" Some people say that it will be 4 times the design load, i.e. 576 lbs. per sq. ft., but in our opinion we should add to 60 lbs. (the dead load), 4 times the superimposed load, which gives 396 lbs. per sq. ft., this being a very different result. The ultimate load, 576 lbs. per sq. ft., corresponds to a load test factor of more than 6 on the superimposed load, and we believe there is some danger of this difference becoming overlooked.

QUALITY OF WATER FOR CONCRETE.

A ROUGH mixture of stone, sand, cement and water used to be considered good enough for concrete. Proportions and rules for mixing and placing were specified, but little else. Increasing use of the material, coupled with rapid improvement in the quality of cement, caused investigation to be made, and reports came from all quarters dealing with the production of good concrete. The evidence was generally in agreement, but contradictions did, and still do, exist. Nevertheless, there is now a mass of fairly reliable data which tells us what to expect when certain aggregates are mixed in certain proportions with definite amounts of cement and water. And with a little care in measuring proportions it is possible to predict the probable strength and nature of the resulting concrete with some degree of accuracy.

This question of proportioning, however, is still far from settled even when dealing with pure ingredients, and the information to hand is still less definite when impurities are present. Impurity in the aggregates has been considered to some extent, but the effect of impure mixing water has received but scant notice. This is doubtless in some measure due to the fact that, in this country at any rate, a good cheap supply of reasonably pure water is nearly always available, and the question of using polluted or otherwise doubtful water has not been sufficiently emphasised to attract the attention of research workers. Specifications have erred on the side of safety by insisting on rain-water or its equivalent.

Instances can be visualised, however, where knowledge of the effect of impurities in mixing water would be of value, and as any new facts connected with the subject of concrete are welcome, we think the report on "Impure Waters for Mixing Concrete," given elsewhere in this issue, will be of interest. Six thousand tests, when properly carried out, must provide an abundance of reliable data, more especially when most of the possible variables are taken into account. Conclusion 32 states that "the important point is not whether impurities are present, but do the impurities occur in injurious quantities ?" This might have been anticipated, and it seems a pity that there is not a compact list, giving percentages of impurities for definite strength-ratios. No doubt this will come later, when the question of revising the specifications for mixing water will come to the front; but it will not be an easy matter to give a full list of impurities which will be allowed, with different percentages for different conditions. In isolated cases this cumbersome specification could be avoided by reference to a definite water supply, and in general it would appear advisable to have a comprehensive standard specification to which reference could be made in a couple of lines. Evidently there is yet much to be done in this field of research. Certain authorities have recommended the use of common salt in concrete for the purpose of lowering the freezing point, and we would draw their attention to Conclusions 1, 9, 13 and 14. Further tests still need to be made, but there is sufficient evidence to show that the addition of common salt in concrete cannot be recommended unless the requisite allowance for reduction in strength is made.

In considering these results we must not lose our sense of proportion, for it is abundantly clear that quantity of mixing water is of more importance than quality; and to get a correct perspective of the subject these results should be considered together with those which deal with the quantity of water to be used and which have appeared in previous issues of this journal.

THE SPONTANEOUS HEATING OF CONCRETE.

THERE is reason to believe that many engaged in concrete construction do not yet realise that the setting of cement gives rise to a considerable development of heat, and in consequence concrete itself becomes hot in the early stages of hardening. The heat development is particularly noticeable in large masses of concrete where the heat is not readily dissipated from the surface, and in such cases it is not uncommon to find that the concrete "steams" when the shuttering is removed. Fears are sometimes expressed that this behaviour is indicative of a hot or unsound cement, but this is not the case. The hardening of cement is a chemical process, and the more active the cement the greater the amount of heat units developed in a shorter time, and in consequence the temperature rise is higher. Aluminous cement, which hardens exceedingly rapidly, is notorious in this connection, and the temperature rise during hardening is very remarkable in some cases.

Some figures recently published in the United States show that a thermometer when inserted at 5 p.m. into a mass of freshly-laid concrete forming a bridge pier registered 46° F.; at midnight the temperature indicated by the thermometer was 60° F., next morning it was 76° F.; after 3 days it was 100° F.; and after 15 days the maximum of 116° F. was reached. The fact that such temperatures as these are possible in the interior of concrete emphasises the importance of keeping concrete moist for a fortnight after mixing, in order to avoid loss by evaporation of water needed for the setting process, and also to avoid contraction.

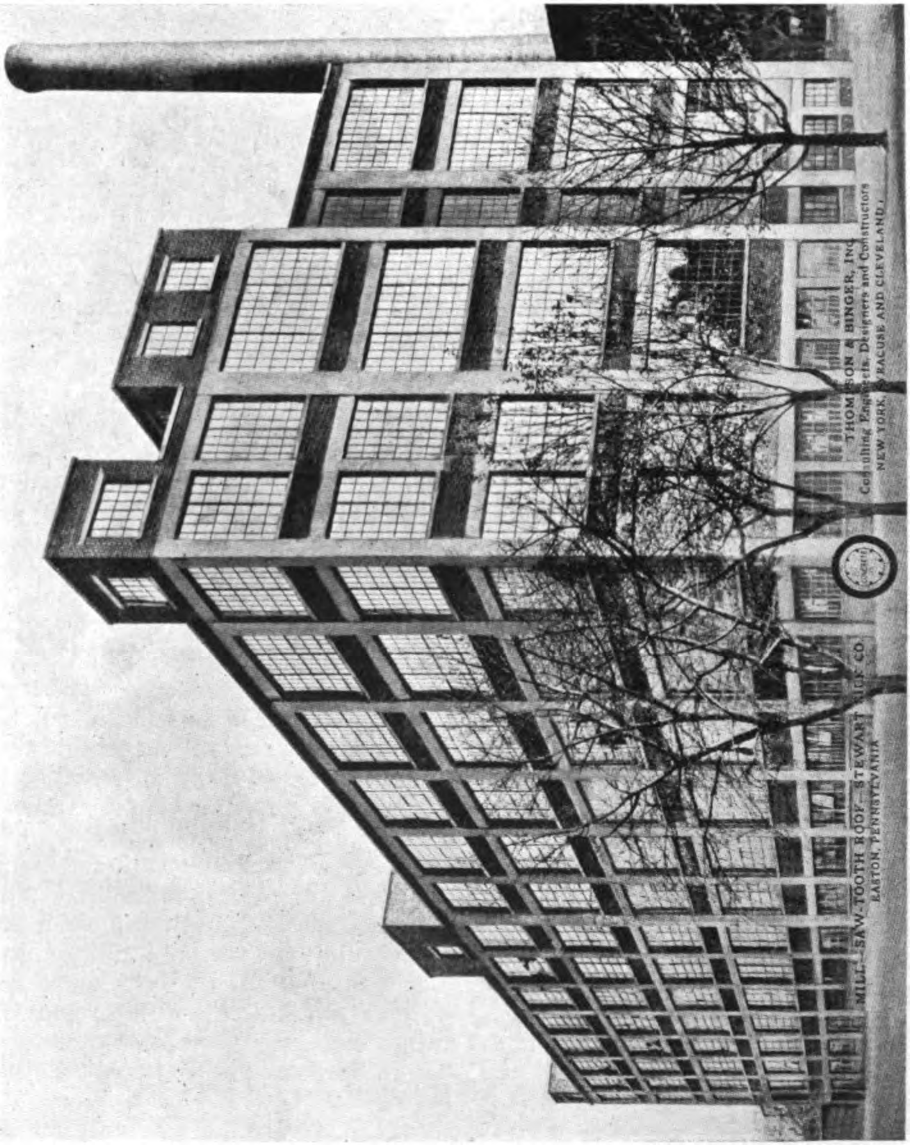
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FIG. 1.—SILK MILL: REINFORCED CONCRETE FRAME; RED BRICK CURTAIN AND PARAPET WALLS. (*See p.* 481.)

EXTERIOR TREATMENT OF CONCRETE INDUSTRIAL BUILDINGS.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

It is a very prevalent idea in Great Britain that although concrete may be used successfully for the structural part of a building yet it has no artistic merit, and therefore should always be covered from view. This idea probably exists because most people have never seen a concrete building where the concrete frame is exposed; or if they have, no attempt had been made to consider the architectural possibilities of concrete either by itself or in combination with brick.

If a new industrial building is to be built of concrete the owner will generally insist that the concrete frame is to be covered from sight, and the architect will generally have the same opinion. Hence the exposed concrete will be covered with a veneer of brick or other material. This is not only an unnecessary added expense, but the result obtained is no better architecturally than if the concrete frame had been exposed and artistically treated.

An ordinary factory or warehouse building with a wholly brick exterior is usually monotonous and seldom has any beauty—in fact, it is usually ugly; but the same building, carefully designed, with an exterior of concrete or concrete and brick each in its right place, can have considerable artistic merit. Simplicity of treatment is the keynote of success; any attempt to form elaborate mouldings or to try to imitate cut-stone work usually leads to a poor looking structure.

There is a considerable field for the ingenuity of architects and engineers in developing methods of combining concrete with brick, in studying surface finish, coloured cement and coloured aggregates, and in the choice of suitable inserts of other materials as ornamentation.

In America this prejudice against exposed concrete has almost entirely disappeared, and practically every concrete industrial building is of the exposed-frame type. A few examples of American buildings are given here to show how simple and economical it is to treat a concrete frame building artistically. Although more elaborate treatments are often used, these buildings have been chosen for their simplicity.

The architectural treatment should depend upon the use to which the building is to be put—a design suitable for a power house would not do for a mill or factory.

General outline is the first consideration architecturally. Symmetry is usually desirable, and an odd number of bays is more easily treated than an even number. End bays should be different from the others, a very suitable treatment being to create a tower effect. After the general outline is chosen, proportion of concrete sizes is the next consideration. The relative dimensions of columns, window lintels, cornice, etc., usually depend more on architectural than structural requirements.

The general outline and relative concrete sizes having been determined, the next question is the type of curtain wall and cornice and the ornamentation of the concrete. A few examples of different classes of structures will be taken. In general, brick curtain walls have been combined with the concrete frame to give the contrast in colour, and ornamentation of the concrete is by means of coloured tile inserts or slots.

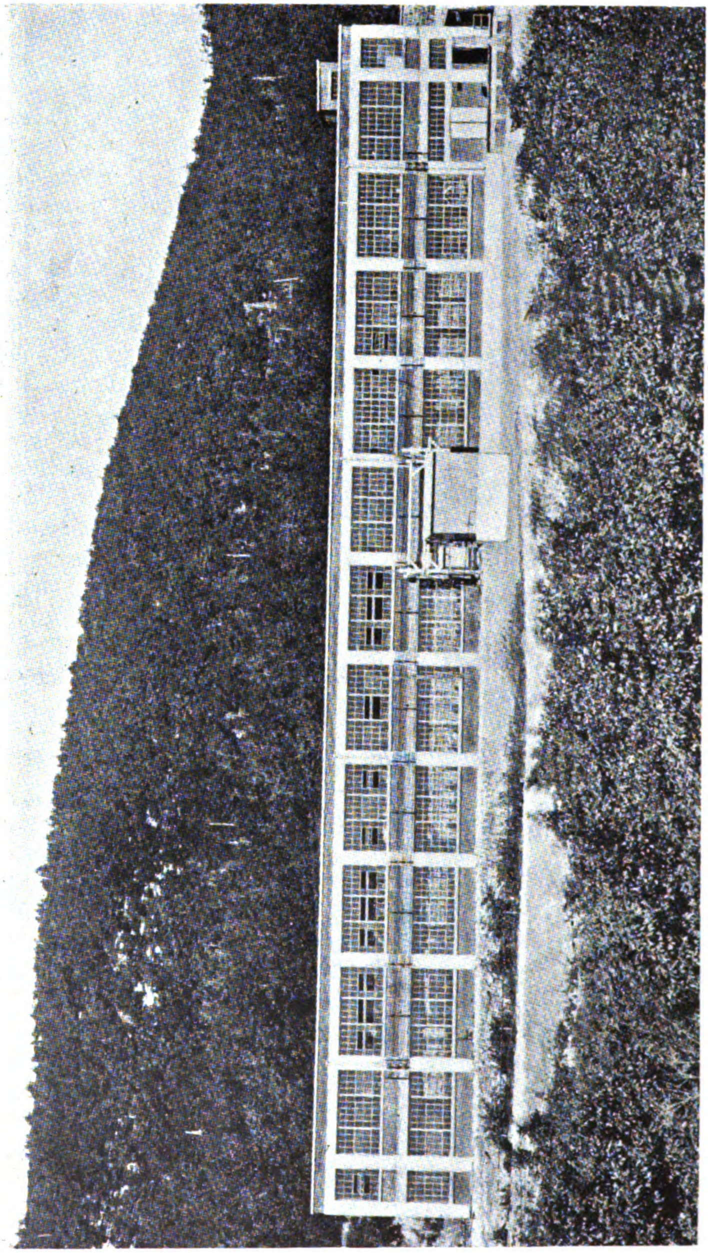


FIG. 2.—SILK MILL; REINFORCED CONCRETE FRAME; RED BRICK CURTAIN WALLS.

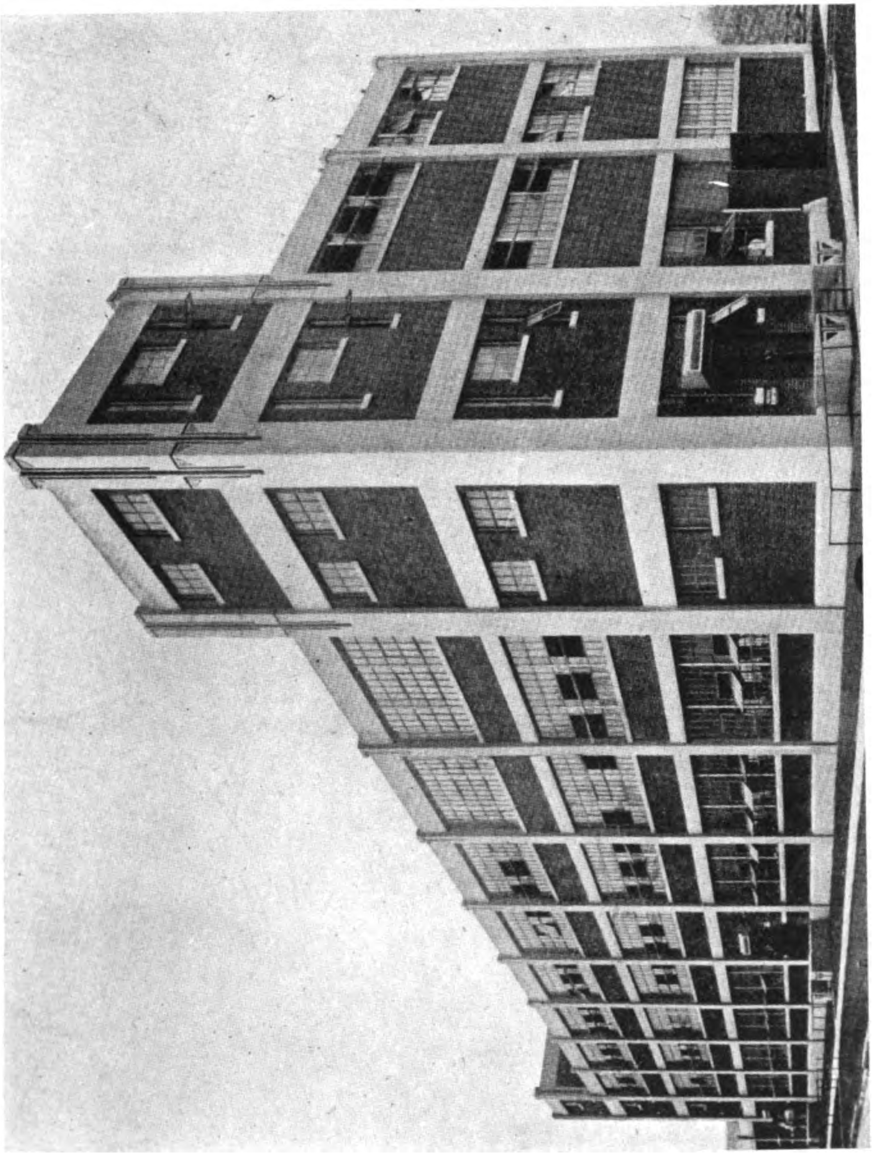


FIG. 3.—FACTORY BUILDING: REINFORCED CONCRETE FRAME; RED BRICK CURTAIN WALLS.

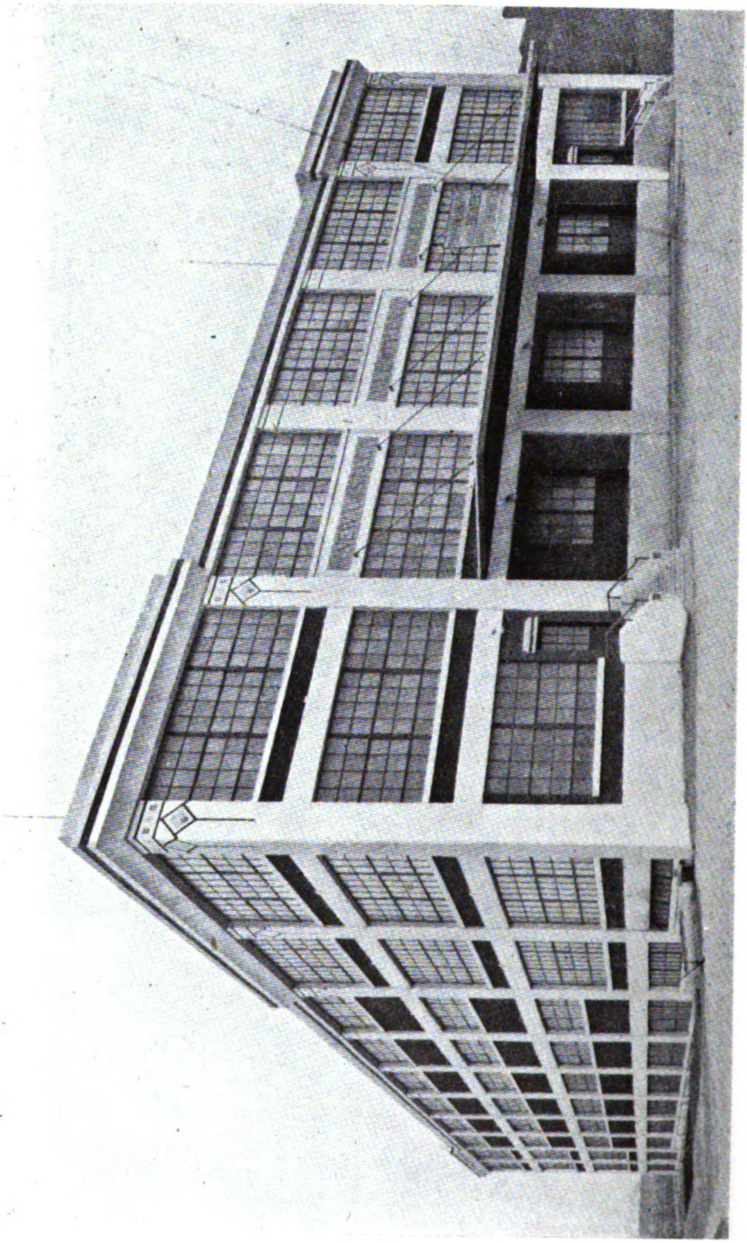


FIG. 5.—WAREHOUSE: REINFORCED CONCRETE FRAME; DECORATED WITH COLOURED CONCRETE TILES AND PAINTED ORNAMENTS.

Examples of six classes of buildings are shown, namely, mills, factories, warehouses, storage buildings, power houses, and a retail store. All except the last are industrial buildings, where cost had to be kept to a minimum and so no elaborate decoration was attempted, the architectural effect being obtained by combination of colours, relative proportion of concrete sizes, and the simplest of ornaments.

Mill buildings are generally the simplest and cheapest types of concrete buildings. In *Figs.* 1 and 2 architectural effect is obtained solely by symmetry, contrast in colour between the red brick curtain and parapet walls, and the painted white concrete frame. Long unbroken lines are the main features of this simplest of all concrete exteriors. Stairways and elevators are usually placed in end bays, so that relief from equal spans throughout is obtained by making

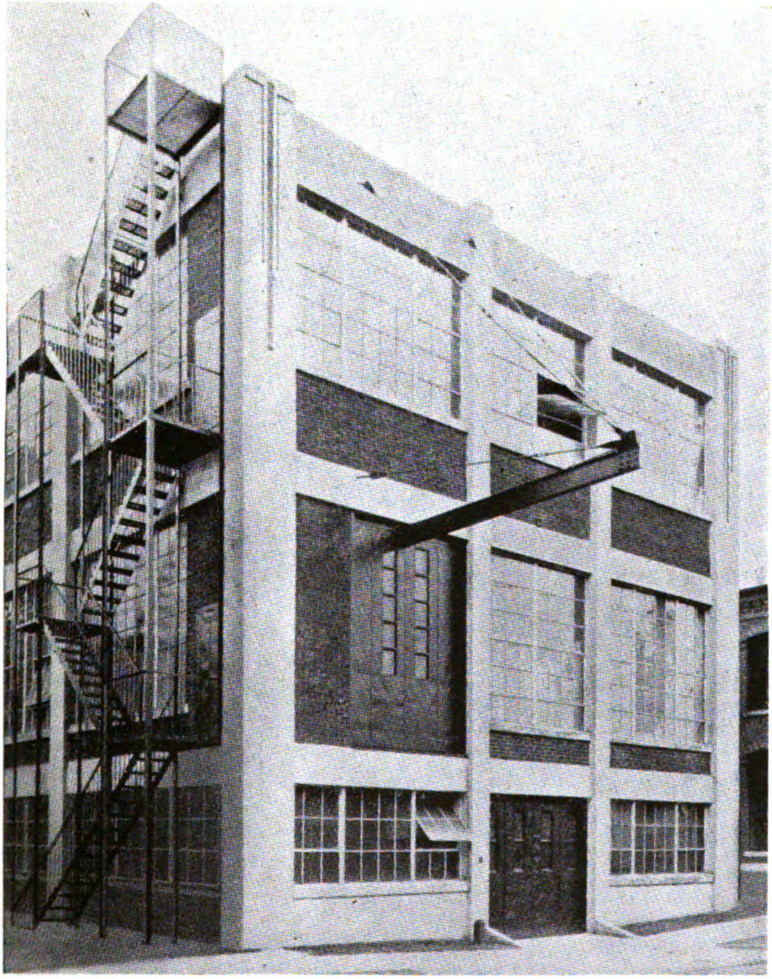


Fig. 4.—FACTORY: REINFORCED CONCRETE FRAME; RED BRICK CURTAIN WALLS.

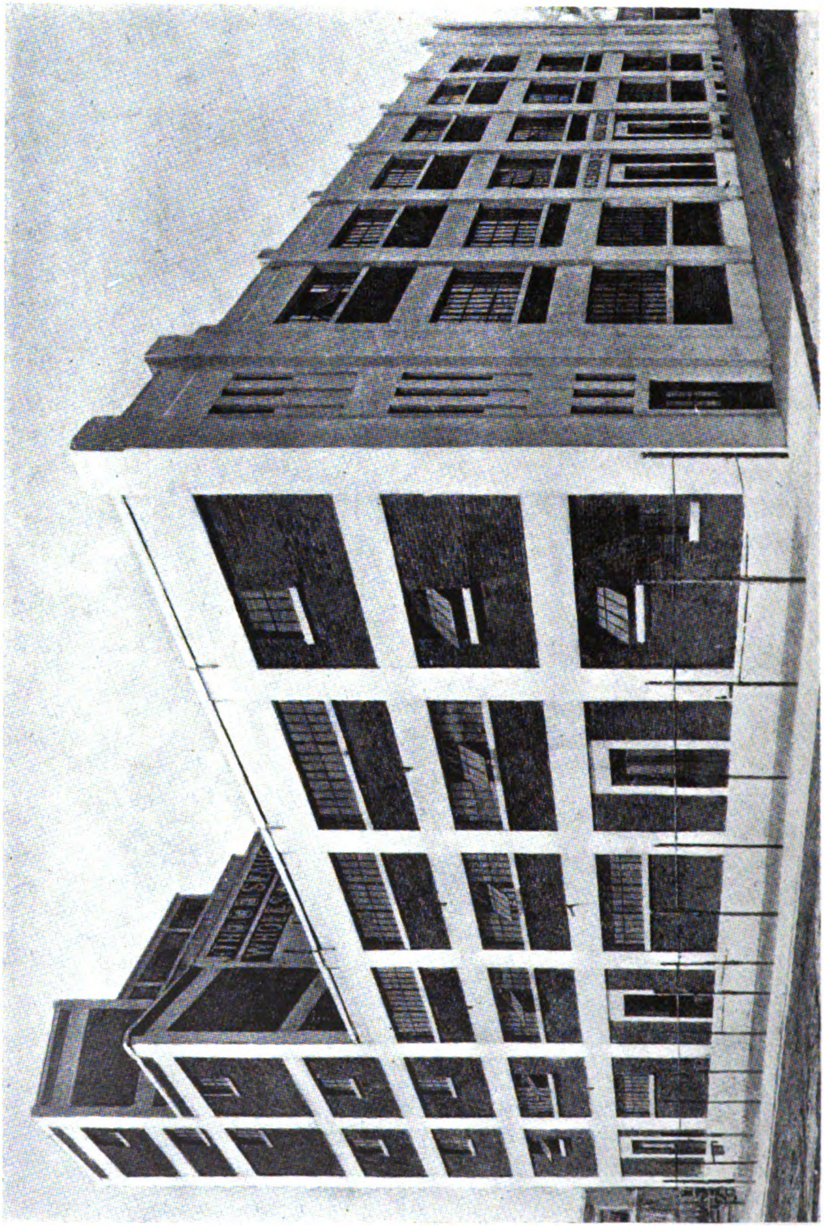


Fig. 6.—WAREHOUSE: REINFORCED CONCRETE FRAME WITH BRICK FILLING; END BAYS ENTIRELY IN REINFORCED CONCRETE.

these bays shorter than the others. These buildings require the maximum of light, and special attention is given to obtaining the greatest possible window area.

In designing factory buildings a little more attention is usually given to the external appearance. *Fig.* 3 is an example of a typical factory. It has symmetry, proportion, contrast in colour, and end tower effect. Again maximum light is required, so wall columns are made as narrow as possible. Unbroken vertical lines are obtained by setting back lintels and curtain walls 4 in. Stairs and elevators are placed in end bays, and the columns in these bays are made heavier and carried up above the roof both to support the penthouses and to give a tower effect. The exposed concrete is painted white, and the curtain walls are dark red hollow brick laid in red mortar with flush joints. The plain

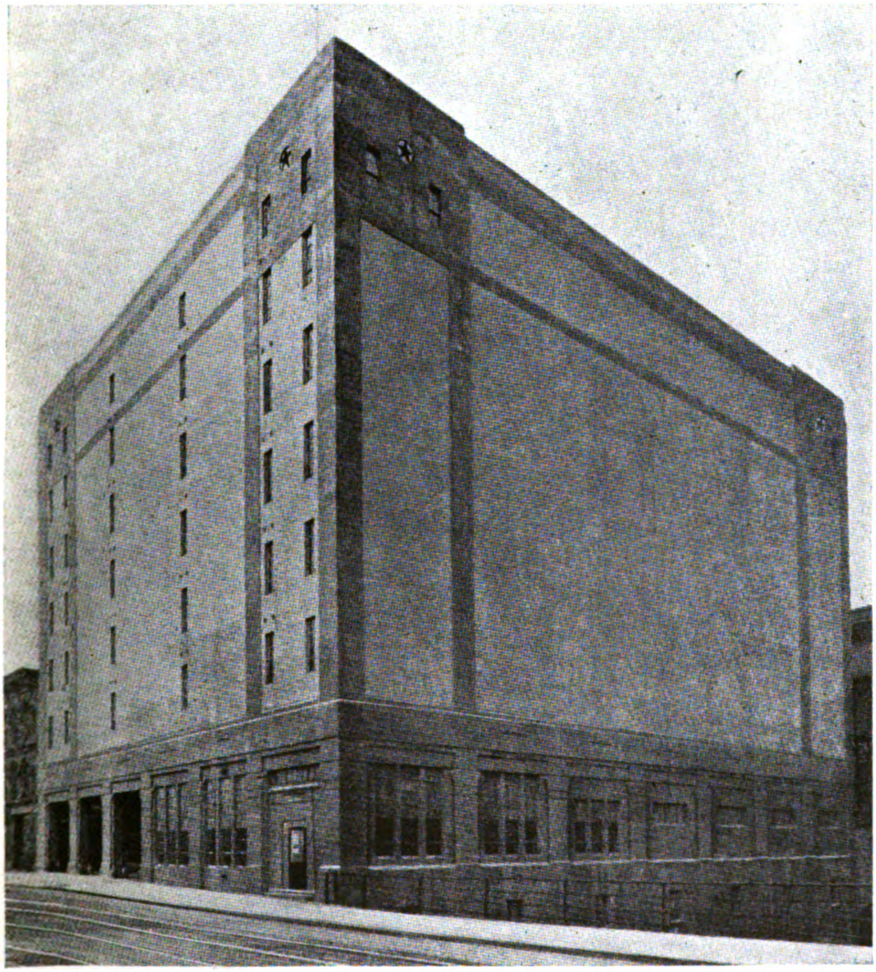


Fig. 7.—STOREHOUSE: LOWER STORY WHOLLY IN CONCRETE. UPPER STORIES, CONCRETE AND LIGHT COLOURED BRICK.

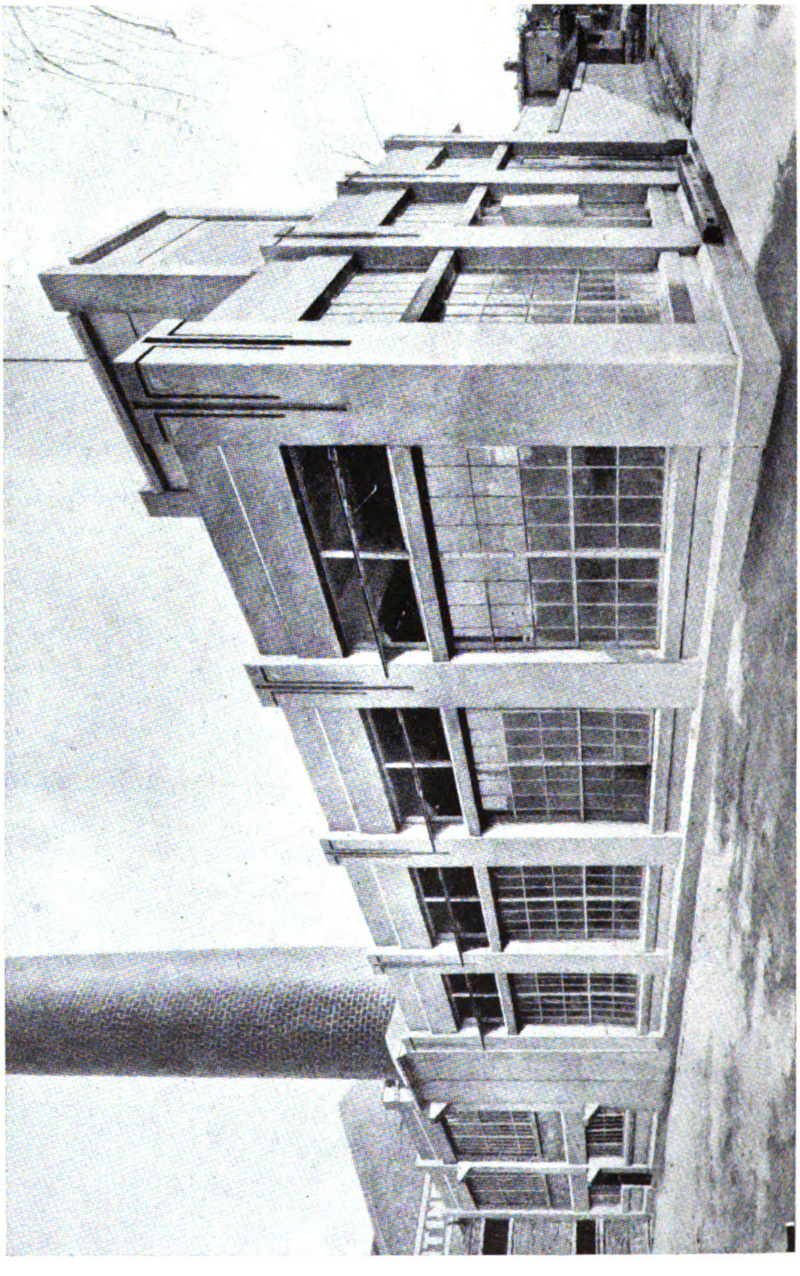


Fig. 8.—POWER HOUSE: ENTIRELY BUILT OF REINFORCED CONCRETE.

concrete columns are relieved by slots about 1½ in. deep, painted black. Black-painted slots of various designs are a very effective means of finishing off concrete columns, and they add greatly to the appearance of the building. Concrete steps and side-walls, on which the ornaments are repeated, and concrete hoods on which is the name of the firm, form simple but effective entrances to the building.

Fig. 4 is a simple factory built for the same owner, so that the same general design was adopted as in *Fig.* 3.

Both mill and factory buildings should be designed to give a light, airy, and cheerful effect. Warehouses may be designed a little more massive looking than factories. Columns, lintels, and coping walls can be made heavier and the window area cut down, increasing the proportion of brick wall to concrete. As warehouses are designed for greater live loads than factories, heavier concrete sizes are required structurally.

Fig. 5 is an example of good warehouse design. Symmetry, proportion, colour, and effective treatment of concrete have all been considered. End bays have been emphasised by changing the column ornaments and projecting out the cornice. Ornamentation of the columns is by means of inserted coloured tiles and black-painted slots. The concrete is painted white, the brick walls are red, and the white colour of the cornice is relieved by a continuous recessed black band.

In *Fig.* 6 the two end bays containing the stairways are treated wholly in concrete.

Storage buildings where goods are stored for more or less long periods require few windows, as natural lighting is not important. This class of building is one of the most difficult to treat architecturally in concrete because of the large areas of blank wall with few openings.

Fig. 7 is a storehouse designed to give an impression of strength and solid mass, to inspire confidence in a prospective customer. The first story, part of which is occupied by offices, is carried out entirely in concrete. The stories above, used for storage only, require little light ; hence the absence of large windows, which also means a saving in the cost of heating the building. To avoid a chess-board effect all lintels and all columns, except those in end bays, are set back and faced with brick. Each corner of the building is given a tower effect, and the towers are connected by exposing the lintels. The concrete was not painted and sand-lime brick was used in the curtain walls to avoid sharp contrasts in colour, the colour of the brick blending with that of the concrete. The company's trade-mark is carried out in coloured tiles at the top of each tower. The building adjoins the main railroad station, and is only a short distance from the centre of the city ; therefore considerable thought had to be given to its architectural appearance and many studies were made before a final design was selected.

Power houses can be very successfully designed in concrete. A massive appearance and plenty of light are desirable features. *Fig.* 8 shows a power house where all architectural features are carried out in concrete, no brick being used. The appearance is obtained by suitable proportioning of concrete dimensions. As it was built for the same owners as *Figs.* 3 and 4, similar column ornamentation was used.

Most of the buildings already mentioned were built in the industrial sections of cities, and it may be said that concrete may be all very well there but could not be used for a building in, say, a main shopping street.

Fig. 9, however, will show that this is not so. This shows the largest department store in the main street of a town, where it stands out in comparison with buildings of brick and cut-stone. The concrete is painted white, the ornaments are coloured tiles, and the slots are painted black. A little ornamental ironwork and coloured glass windows add greatly to the appearance. The building is designed so that additional stories can be added in the future.

Of course, when concrete is exposed to view particular care must be taken with the formwork to have all lines straight and true, and to see that it is well braced so that there will be no bulges. The concrete must be carefully spaded so that there will be no voids and exposed aggregate, etc., which would have to be patched. Another important point is to design the columns for bending, as they will tend to crack at the junction with the floor if not properly reinforced. Also a liberal supply of small bar reinforcing should be used in the lintels and cornices and all small sections, to prevent cracks from temperature changes.

In all these buildings no special surface treatment was given other than rubbing down with carborundum brick and water to which is added a little cement, as soon as possible after stripping the forms.

It must be remembered that concrete architecture is a comparatively new subject and it is better to develop new types suitable to the material than to try to imitate types that have been developed for other materials of construction.

All the buildings illustrated have been designed and built by Messrs. Thompson & Binger, of New York and Syracuse.

STRESSES IN THIN CIRCULAR PIPES, ETC., UNDER SYMMETRICAL LOADS.

II.

By G. P. MANNING, M.Eng., A.M.Inst.C.E.

WHEN a large isolated cylinder, such as a large circular silo, is subjected to wind pressure on one elevation, this pressure tends to force in and flatten that part of the cylinder facing the direction of the wind. By taking a small piece of the silo, cut off by two horizontal planes drawn close together, we can treat this piece as a thin circular ring which is distorted and stressed due to the fact that the wind pressure is applied on one semi-circle only.

Example.—An isolated circular silo of considerable height H is empty and is subjected to a horizontal wind pressure of p pounds per square foot of elevation. What local bending moments will this pressure cause at a horizontal section about half-way up the silo? The radius of the silo is r.

This last condition has been put in because the attachment of the walls to the hopper bottom or to the foundation will produce local bending moments and restraints near the bottom of the silo, and the provision of a roof or superstructure might similarly modify the deflections near the top. In the centre portion of the height each small horizontal ring will be free to take up its proper distortion under load in accordance with the conditions stated in the following argument.

This problem has one fundamental difference from the last problem cited.* In the case of the pipe we can look on each short length of pipe as self-supporting. Each foot run of pipe carries exactly similar loads, and each foot run therefore exerts no stresses on the next length of pipe. In the case of the silo, the whole structure has to act as a large cantilever, the upper part at any horizontal section being held in place by shear forces and moments supplied by the bottom half.

Before we can arrive at the local moments we must examine the beam action of the whole structure.

Referring to *Fig.* 4:—

Let F = total shear force on a horizontal section.
$F + \delta F$ = total shear force on an adjoining section.
δH = a small increment of height.

The loading is symmetrical about the diameter $a\ b$, and $c\ d$ (at right angles to $a\ b$) will represent the neutral axis of the section when the whole silo acts as a beam.

If we examine the circular ring $a\ c\ b\ d$, whose height is δH between two horizontal planes, we see that it is kept in equilibrium by:—

(1) Various compressive and tensile stresses acting at right angles to the horizontal planes.

(2) Shear forces F and $F + \delta H$ (in opposite directions).

(3) Wind pressure on the elevation $= \delta H \times 2r \times p$.

The vertical forces cannot produce bending of the ring $a\ c\ b\ d$.

Confining our attention to the horizontal forces only:—

$$F + 2\ pr\ \delta H = F + \delta F.$$
$$2\ pr\ \delta H = \delta F$$

---

* *Concrete and Constructional Engineering*, July, 1924.

The net forces, therefore, which tend to distort the ring *a c b d* (whose height is δH) are :—

(I) Wind pressure p acting on *c b d*, the intensity per unit run of circumference being greatest at *b*.

(II) A net shear force δH distributed round the whole circle *a c b d*, being greatest in intensity at *c* and *d* (the neutral axis of the silo as a whole).

The intensity of shear can be found by applying the usual theory of elastic bending to the particular case of a beam having a hollow circular cross section (*see* Morley's "Strength of Materials") and the intensity of net shear at any point is found to be (omitting the analysis).

$$f = \frac{\delta F}{\pi r} \sin^2 a \text{ (acting parallel to } a\,b).$$

The total shear on a small unit of ring $r\,\delta a$ (*see Fig.* 4)

$$= fr\,\delta a = \frac{\delta F}{\pi} \sin^2 a\,\delta a.$$

The shear force on the small element of arc between $a = 40°$ and $a = 60$ may be computed approximately by writing

$$\delta a = (60° - 40°) = 20° = \frac{\pi \times 20}{180} \text{ radians}$$

$$\text{and } a \text{ (average value)} = \frac{40° + 60°}{2} = 50°, \sin a = 0{\cdot}766.$$

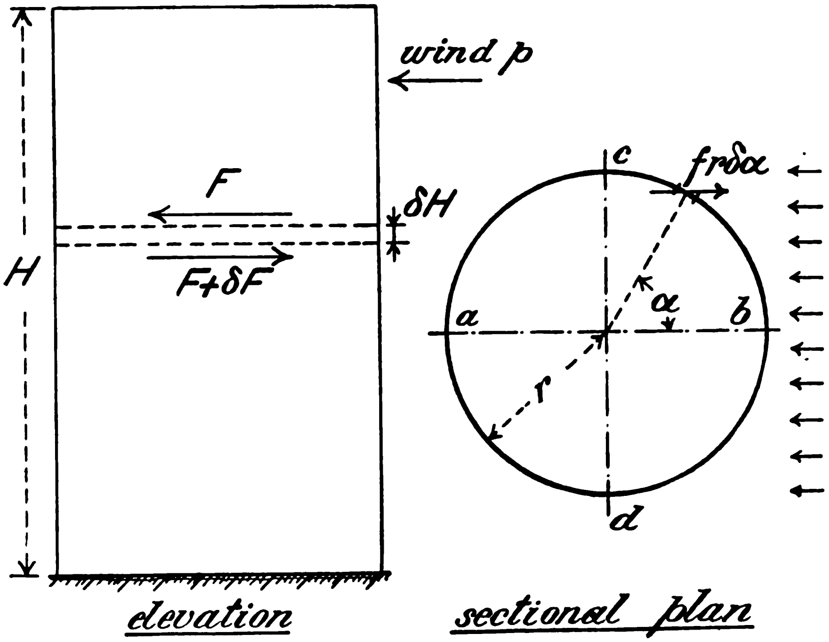


Fig. 4.

$\therefore$ Total shear on element of arc (approx.)

$$= \frac{\delta F}{\pi} \times (0{\cdot}766)^2 \times \frac{\pi \times 20}{180}$$

$$= \frac{\delta F}{9} \times {\cdot}587 = 0{\cdot}0652\ \delta F.$$

Similarly we have, taking the semi-circle *a c b*,

Arc	Net shear on arc	Average value of α
0° to 20°	$0{\cdot}0034\ \delta F$	10°
20° to 40°	$0{\cdot}0278\ \delta F$	30°
40° to 60°	$0{\cdot}0652\ \delta F$	50°
60° to 80°	$0{\cdot}0981\ \delta F$	70°
80° to 100°	$0{\cdot}1111\ \delta F$	90°
100° to 120°	$0{\cdot}0981\ \delta F$	110°
120° to 140°	$0{\cdot}0652\ \delta F$	130°
140° to 160°	$0{\cdot}0278\ \delta F$	150°
160° to 180°	$0{\cdot}0034\ \delta F$	170°
Total	$0{\cdot}5001\ \delta F$	

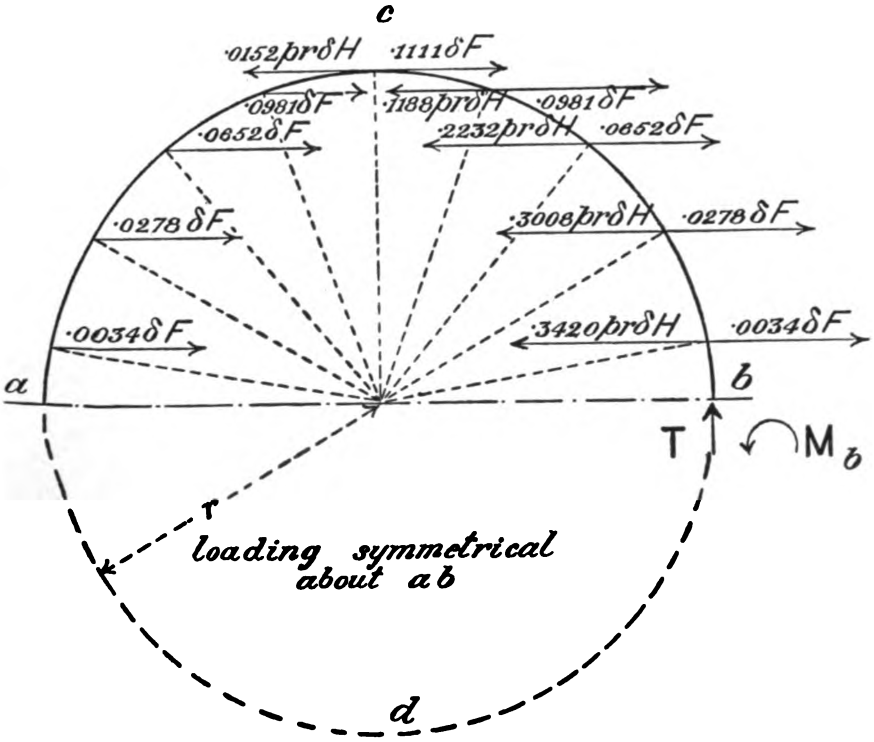


FIG. 5.

The total shear on the semi-circle should obviously be $\frac{\delta F}{2}$, the small error being due to the fact that we have taken arcs of appreciable length (20° each) instead of taking arcs infinitesimally small.

The wind pressure may be assumed as p per unit area of elevation of each arc. (This is not strictly correct, as the actual distribution will follow some sort of a " butterfly " diagram.)

For example :—arc 20° to 40°

$$\text{wind pressure} = p\ \delta H \times (r \sin 40^\circ - r \sin 20^\circ)$$
$$= 0{\cdot}3008\ pr\ \delta H$$
$$\text{acting at } a = 30^\circ$$

The total loading on semi-circle $a\ c\ b$ is shown in *Fig.* 5.

Tabulated values of the loads and stresses are shown in *Fig.* 6, obtained by using the factors in *Table A*. (The values are given to five figures for ease in addition and subtraction. They are only correct to about 2 per cent.)

Referring to *Fig.* 5 we see that the semi-circle $a\ c\ b$ has been divided into

LOAD	∠°	M_b	T
$-\cdot 0034\ \delta F$	10°	$-\cdot 00162\ \delta F.r$	$+\cdot 00003\ \delta F$
$-\cdot 0278\ \delta F$	30°	$-\cdot 00718\ \delta F.r$	$+\cdot 00222\ \delta F$
$-\cdot 0652\ \delta F$	50°	$-\cdot 01010\ \delta F.r$	$+\cdot 01230\ \delta F$
$-\cdot 0981\ \delta F$	70°	$-\cdot 01320\ \delta F.r$	$+\cdot 02760\ \delta F$
$-\cdot 1111\ \delta F$	90°	$-\cdot 01500\ \delta F.r$	$+\cdot 03520\ \delta F$
$-\cdot 0981\ \delta F$	110°	$-\cdot 01240\ \delta F.r$	$+\cdot 02760\ \delta F$
$-\cdot 0652\ \delta F$	130°	$-\cdot 00570\ \delta F.r$	$+\cdot 01230\ \delta F$
$-\cdot 0278\ \delta F$	150°	$-\cdot 00108\ \delta F.r$	$+\cdot 00222\ \delta F$
$-\cdot 0034\ \delta F$	170°	$-\cdot 00001\ \delta F.r$	$+\cdot 00003\ \delta F$
$+\cdot 3420\ pr\delta H$	10°	$+\cdot 16300\ pr^2\delta H$	$-\cdot 00342\ pr\delta H$
$+\cdot 3008\ pr\delta H$	30°	$+\cdot 07710\ pr^2\delta H$	$-\cdot 02410\ pr\delta H$
$+\cdot 2232\ pr\delta H$	50°	$+\cdot 03460\ pr^2\delta H$	$-\cdot 04190\ pr\delta H$
$+\cdot 1188\ pr\delta H$	70°	$+\cdot 01590\ pr^2\delta H$	$-\cdot 03350\ pr\delta H$
$+\cdot 0152\ pr\delta H$	90°	$+\cdot 00208\ pr^2\delta H$	$-\cdot 00485\ pr\delta H$

FIG. 6.

9 equal arcs of 20° and that the load on each arc has been assumed to act through the mid-point of each arc. On the quadrant *c b* we have both shear forces and wind pressure (acting in opposite directions). On the quadrant *a c* we have shear forces only.

The total value of M_b is $+ 0{\cdot}29268\, pr^2\, \delta H - 0{\cdot}06629\, \partial F r$.

$$\text{Now } \delta F = 2\, pr\, \delta H$$
$$\therefore M_b = (+ 0{\cdot}29268\, pr^2\, \delta H - 0{\cdot}13258\, pr^2\, \delta H)$$
$$= + 0{\cdot}160\, pr^2\, \delta H \text{ on a height } \delta H.$$
$$\text{Similarly } T = + 0{\cdot}131\, pr\, \delta H \text{ on a height } \delta H.$$

The local moment per unit height is

$$M_b = + 0{\cdot}160\, pr^2$$
$$\text{and } T = + 0{\cdot}131\, pr. \text{ per unit height.}$$

$$\text{If } p = 40 \text{ lbs. per sq. ft. and } r = 20 \text{ ft.}$$
$$M_b = + 0{\cdot}160 \times 40 \times 20^2 \text{ lbs. ft. per ft. of height}$$
$$= + \underline{2{,}560 \textit{ lbs. ft.}} \text{ (tension on intrados).}$$

Similarly $T = + 0{\cdot}131 \times 40 \times 20 = 105$ *lbs. per ft. of height.*

Stresses at all other points can readily be found by statics.

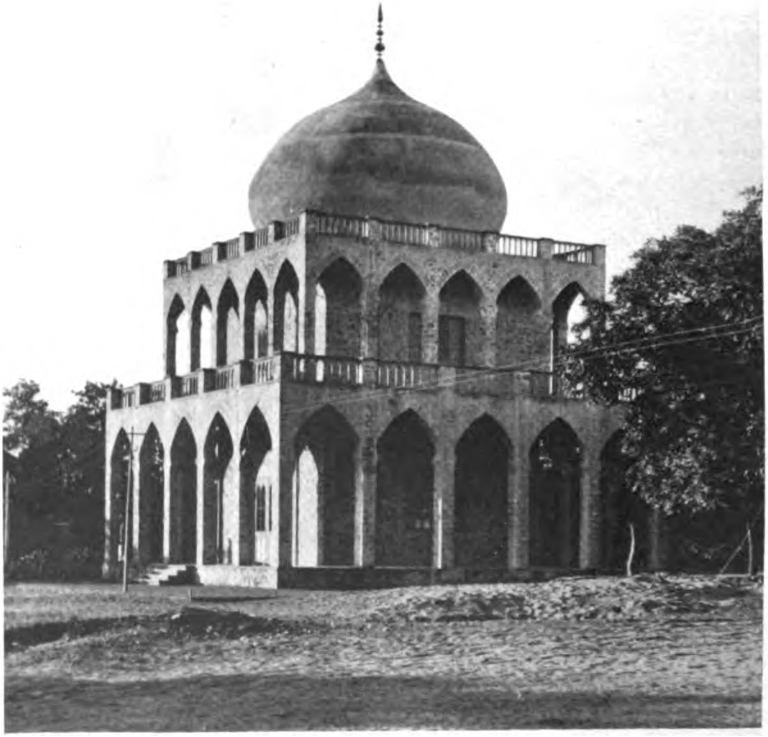
In order to familiarise the reader with the method of using the coefficients in *Table A*, the author suggests working out the problem of a ring subject to a uniform external pressure acting towards the centre at all points. Divide the circumference into arcs of 20°, concentrate the load at the centres of these arcs, resolve into components parallel and at right angles to some selected diameter and compute the values of M_b and T at the end of the chosen diameter. The correct answer to this problem will, of course, be obvious from first principles and will check the working.

A DOMED WATER TOWER.

By S. A. BUNTING, M.A., M.Inst.C.E.

An 18,000-gallon water tank with its base some 35 ft. from ground level was required at Sambhar, Rajputana, to supply the salt colony and the works with fresh water.

The original design showed a plain circular masonry tower 24 ft. internal diameter surmounted by a ferro-concrete tank some 5 ft. deep with a flat base carried on ferro-concrete beams. A similar structure had been built for a water-cooling tower for the power house and had given satisfaction. The power house tower had been fitted with louvres and surmounted by a conical wooden roof, but in the case of the water works, a hemispherical masonry dome was designed. It seemed, however, a pity to put up a structure of this kind at the top of the hill, the most commanding position for some distance round. Moreover, it was



A Domed Water Tower in India.

difficult to utilise the lower part of the building owing to its circular shape and the absence of shade on the walls.

The author decided to attempt something less unsightly and at the same time more capable of use in the lower portion, provided it could be done at no undue expense. The style adopted is that of the 17th-century Moguls, as used in many buildings in Delhi and Agra, mostly mausoleums. No type was strictly adhered to. The main walls are of rubble masonry 1 ft. 6 in. thick, while the floors consist of Rajputana stone slabs carried on ferro-concrete beams. The railings are ferro-concrete, cast in bays between masonry pillars, the twenty bays of each tier being all cast from one mould. They repeat the Mogul arch design, and the masonry pillars of dark reddish brown stone set them off. These pillars also are capped with concrete.

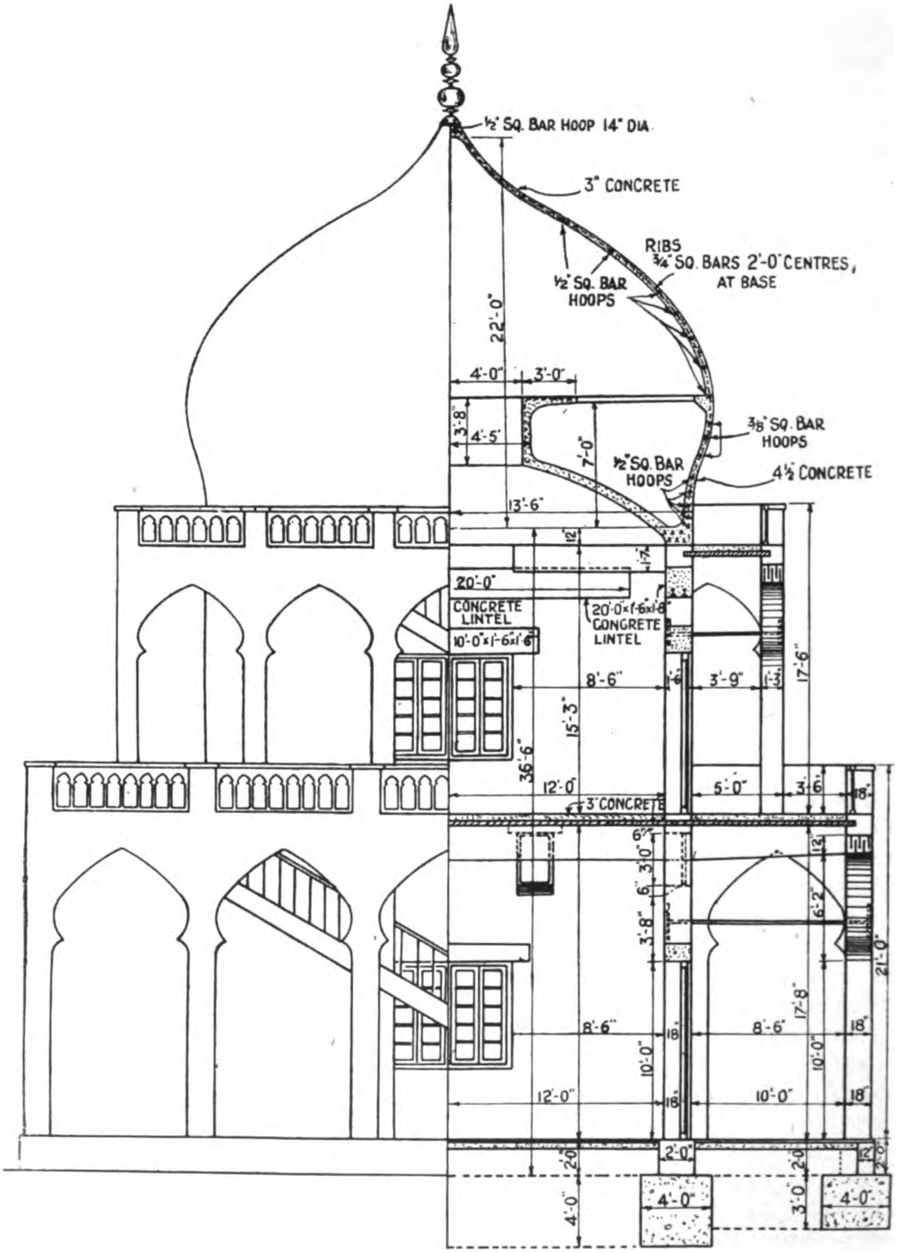
The water is carried between two domes, access to the tank being given through an orifice 8 ft. in diameter in the centre of the inner dome. The whole weight of domes and water is transmitted to the square masonry structure by an octagon of ferro-concrete beams, and distributed evenly over the walls by further ferro-concrete beams just below the octagon.

The bulging shape of the dome has no appreciable effect on the hoop tension. In fact, provided the dome be strongly hooped at the point of maximum diameter the weight of the dome tends to counteract the outward water pressure to some extent. Had the author seen the article on ferro-concrete water tanks in the May issue of "Concrete and Constructional Engineering" in time he would have been inclined to adopt the procedure therein laid down; i.e. build the tank, hoop it, and put the concrete in compression, the eventual water pressure just neutralising that compression. A bulging dome could almost be made to achieve the same result without hoop reinforcement of the water tank itself, but only at the sacrifice of artistic and rational proportions. The inner dome is not reinforced except in the matter of the surrounding rings at the springing, which take the whole of the outward thrust. The whole floor is in compression, which ensures its watertightness. The "C" reinforcement shown round the central orifice is merely to support the annular platform, necessary for inspection of the tank.

Above the water line the hoop reinforcement has to resist the horizontal components of outward thrusts due to the weight of the dome; once fairly round the bulge no more reinforcement is required. Four small windows admit light to the dome, the vertical "shaping" reinforcement having to be bunched somewhat to avoid them. A 2-in. galvanised iron pipe was set in the concrete at the top of the dome, and on to this were threaded the beaten copper vessels which make up the conventional Shah Jehan finial. At the extreme point was fixed a 2000-c.p. lamp, which is almost invisible in daylight and does not detract from the appearance of the finial.

The formwork for these domes was somewhat difficult. The form for the inner dome was carried on a series of trestles set radially, the inner ends of these trestles also supporting a wooden form for the orifice. The form for the outside of this pipe and the annular platform had to be supported on rough cut stones exactly the thickness of the inner dome at these points, the stones being left embedded in the finished concrete. The inner forms of the outer dome were similarly supported on stones the thickness of the concrete.

The outer form of the outer dome consisted of a mud masonry wall reinforced



WATER TOWER WITH FERRO-CONCRETE DOME

with wooden hoops made of planks nailed together. It was 10 ins. thick and followed the bulging shape of the dome, plastered on the inside with lime plaster. This outer wall was only built 8 ft. high at first, and then the whole structure up to the water line was concreted. The inner dome was somewhat troublesome, as workmen had to sit on sloping planks supported by the forms across the uncovered portion and maintain the correct thickness of concrete, the concrete tending to slide down to the bottom if at all too wet.

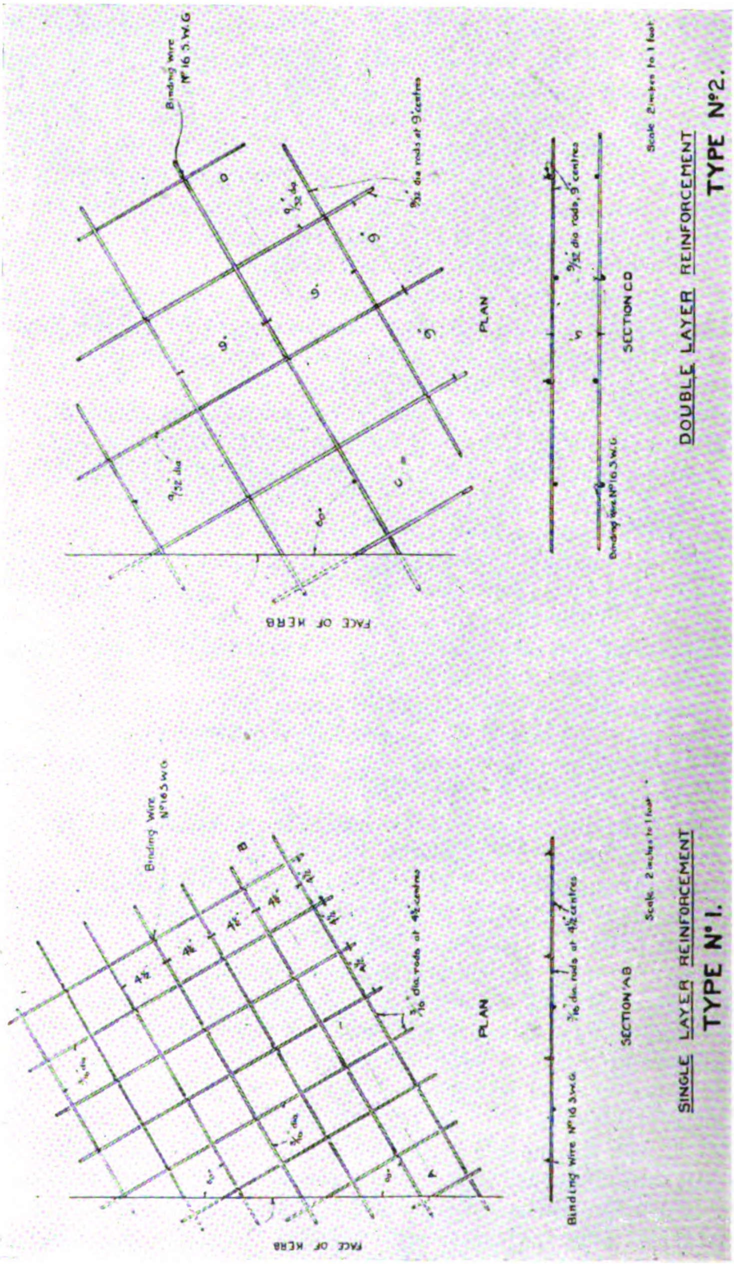
It will be noticed that a ridge runs around the dome at the water line. On the completion of the tank, trestles were erected resting on this ridge and on the annular platform, and the inner forms for the upper dome attached to them. The outer wall was only carried 5 ft. above the water line; above that level the slope of the dome was sufficient to allow of dispensing with an outer form. It is doubtful if any other type of outer form could have been put up so cheaply. A wooden structure would have left polygonal faces hard to disguise, and, moreover, wood was scarce and dear and stone and labour comparatively cheap.

The 3-in. rising main, a 3-in. wash-out pipe with a branch for overflow, a 4-in. pipe for locomotive watering, two 2-in. and three 1½-in. distribution mains, all traversed the concrete, in a sloping direction, into the lowest portion of the tank, being set in place before casting. All had valves just outside the tank operated on the upper verandah.

A week after casting the tank was filled. The inner dome sweated somewhat, while the outer dome only showed one or two patches. Four feet of water were run off and a few bags of cement tipped into the remainder and kept stirred for an hour or two in the hope of sealing some of the pores. This had some effect round the lowest portion of the tank, and had it been left some time doubtless it would have sealed itself further. However, the extra cost of cement plastering the inside was not great, and this was done and the tank again filled. What slight patches still showed then were left, and dried completely in about three days, even with the tank full of water all the time. The tank has since been absolutely watertight and not a trace of sweating can be found.

The inside of the inner dome and orifice, like the walls, was treated with Jaipur marble polish, a mixture of marble dust, white lime, etc., laid on, rubbed down, and polished with cocoanut oil and other ingredients, leaving a polished white finish, practically everlasting in that climate. It has been used for polishing ferro-concrete baths and it stands hot and cold water perfectly, but some ingredient in soap affects it and turns it brown after a time. There was an idea of so treating the outside of the dome also, but it was abandoned. The light grey cement colour blends with the warmer tints of the masonry work and the copper finial shows up well. A white dome could only reduce these effects, and probably would not weather so well.

The chief architectural blemish consists in two ferro-concrete and stone slab staircases against the outside of the main wall on the south side, one from the plinth to the first floor, the other giving access from the first floor to the upper verandah, which is the valve gallery. The original idea was to close in the verandah arches, at least partially, with pierced "marble" screens of ferro-concrete, but during construction it was seen that this would not leave enough light and would have largely detracted from the usefulness of this building, and this omission leaves the staircases exposed to view.


Binding wire No 16 S.W.G.
B
4½"
3/16" dia rods at 4½" centres
3/16" dia
A
PLAN
FACE OF KERB
Binding wire No 16 S.W.G.
3/16" dia rods at 4½" centres
SECTION AB
Scale 2 inches to 1 foot
SINGLE LAYER REINFORCEMENT
TYPE No 1.
Binding wire No 16 S.W.G
9/32" dia rods at 9" centres
9/32" dia
9"
D
C
PLAN
FACE OF KERB
Binding wire No 16 S.W.G.
9/32" dia rods, 9" centres
SECTION CD
Scale 2 inches to 1 foot
DOUBLE LAYER REINFORCEMENT
TYPE No 2.

KINGSTON BY-PASS ROAD: DETAILS OF REINFORCEMENT. (*See p* 501.)

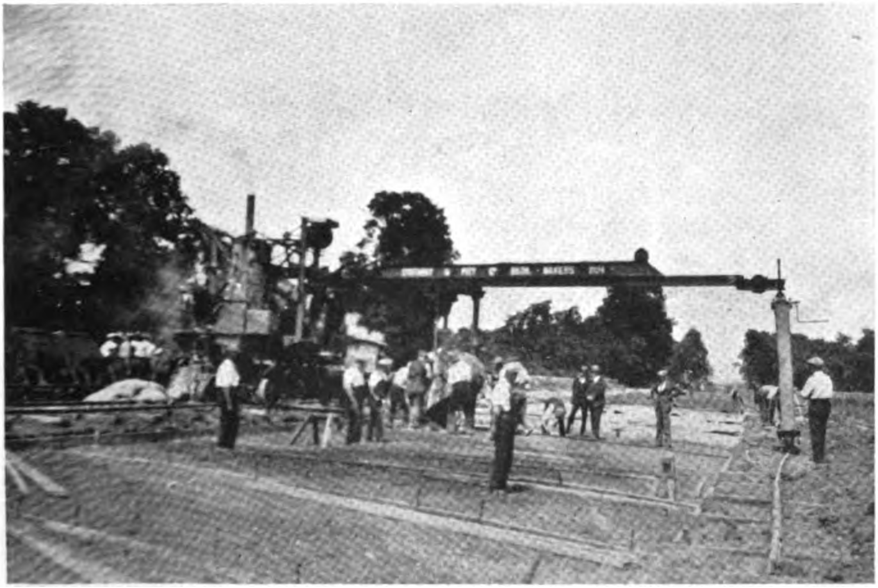
CONCRETE ROADS IN SURREY.

To those who have for many years been advocating the necessity for building roads sufficiently strong to withstand the wear and tear of modern traffic—a case for which one would have thought no special pleading would have been required—the attention now being given to the all-concrete road is a source of considerable gratification. Wherever the construction of a new road is under discussion the claims of the concrete surface are seriously considered, and if the traffic to be carried warrants its use, it is being adopted for a very large proportion of new roads.

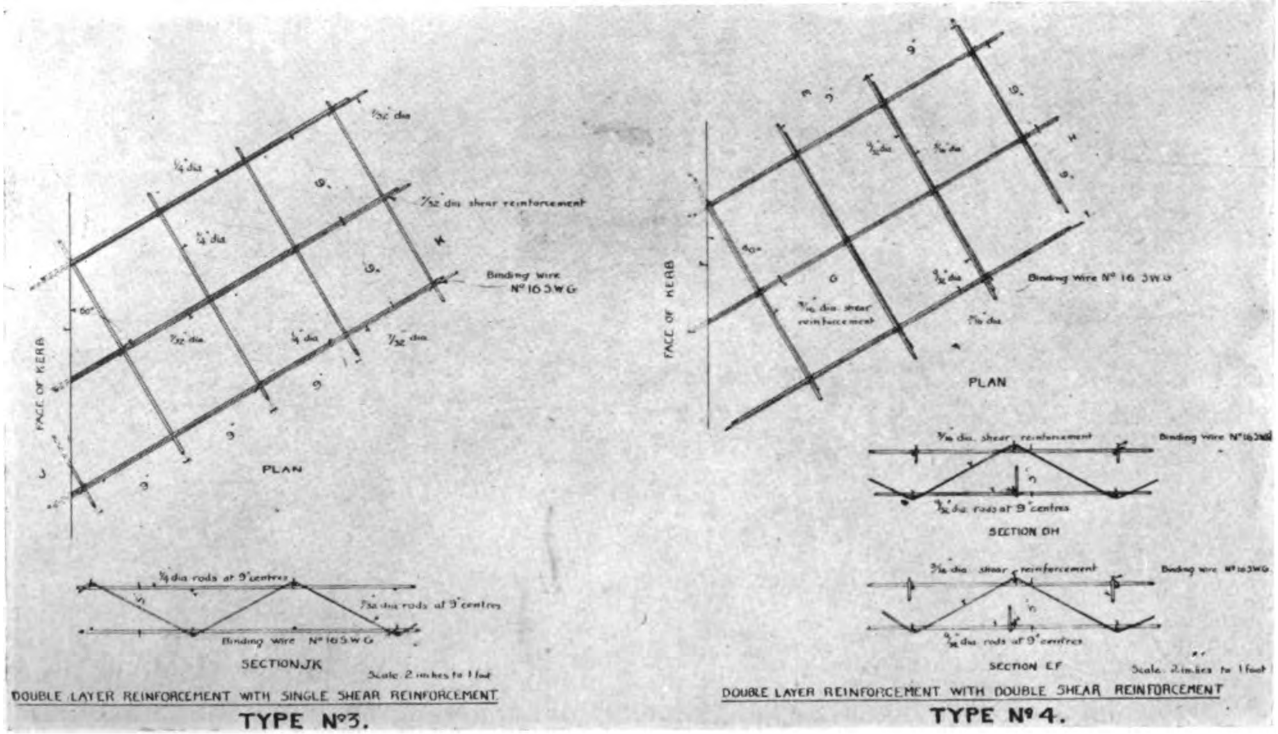
The practical interest which Engineers and Surveyors to local authorities take in the matter was shown recently, when a record gathering of the Institution of Municipal and County Engineers inspected the work of constructing the new Kingston By-pass, which is being so ably carried out under the supervision of Mr. W. P. Robinson, A.M.Inst.C.E., M.I.M. & Cy.E., the County Surveyor of Surrey. This road is on the London–Portsmouth road, and will provide a means of avoiding the busy and narrow roads of Kingston. Starting at Beverley Brook on the London County boundary, and proceeding via Tolworth and Hook to Esher, the new by-pass will also provide a direct route to Esher without touching Kingston and Surbiton, and give direct communication between Merton, Malden, Tolworth, Hook, and Esher, where the existing highways are narrow and tortuous.

The total length of the by-pass, when completed, will be about 9½ miles, and, as with many of the new arterial roads, an ultimate width of 100 ft. exclusive of slopes to embankments and cuttings is provided for. At present, however, a carriageway of 30 ft. and one footpath 8ft. wide only are being paved, thus providing ample width for present requirements and giving scope for extension up to a width of 100 ft. if demanded by the traffic of the future. The portion now being laid is in the centre of the 100-ft. width which has been fenced in, and the remainder is to be kept as a grass verge until it is necessary to widen the paved portion.

The subsoil throughout the length of the road is mostly a stiff sandy clay, which, after grading, is covered with a



Kingston By-Pass Road during Construction.


FACE OF KERB
1/4" dia
7/32" dia
1/4" dia
7/32" dia shear reinforcement
K
9"
9"
Binding wire
N° 16 S.W.G.
60°
7/32" dia
1/4" dia
7/32" dia
9"
9"
9"
J
PLAN
1/4" dia rods at 9" centres
7/32" dia rods at 9" centres
Binding wire N° 16 S.W.G.
SECTION JK
Scale 2 inches to 1 foot
DOUBLE LAYER REINFORCEMENT WITH SINGLE SHEAR REINFORCEMENT
TYPE N°3.
FACE OF KERB
9"
9"
9"
H
9"
9"
9/32" dia
5/16" dia
60°
G
9/32" dia
Binding wire N° 16 S.W.G.
5/16" dia shear reinforcement
5/16" dia
PLAN
5/16" dia. shear reinforcement
Binding wire N° 16 S.W.G.
9/32" dia rods at 9" centres
SECTION GH
5/16" dia shear reinforcement
Binding wire N° 16 S.W.G.
9/32" dia rods at 9" centres
SECTION EF
Scale 2 inches to 1 foot
DOUBLE LAYER REINFORCEMENT WITH DOUBLE SHEAR REINFORCEMENT
TYPE N° 4.

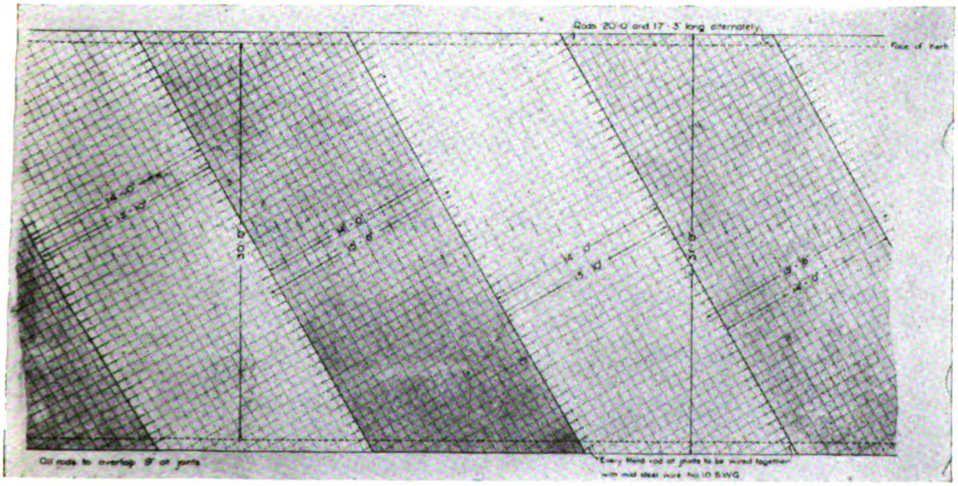
KINGSTON BY-PASS ROAD: DETAILS OF REINFORCEMENT.

bed of clinker well rolled. The carriageway is being laid entirely in reinforced concrete with a total thickness of 8 in., the lower course 6 in. thick and the top course 2 in. thick. The lower course is composed of 4 parts coarse material (60 per cent. by weight passing a 1-in. square mesh and rejected by ½-in. square mesh; 40 per cent. by weight passing ½-in. square mesh and rejected by ⅛-in. square mesh), 2 parts sand, and 1 part British Portland cement. The top, or wearing, course is made of 3 parts coarse material (60 per cent. by weight passing a ¾-in. square mesh, and rejected by a ⅜-in. square mesh; 40 per cent. by weight passing a ⅜-in. square mesh, and rejected by a ⅛-in. square mesh), 1½ parts sand, and 1 part British Portland cement. The coarse material is obtained locally from the valley of the Thames, and is crushed, screened, washed and graded near the site. The sand is specified to conform to the following grading with a margin of 5 per cent.:—

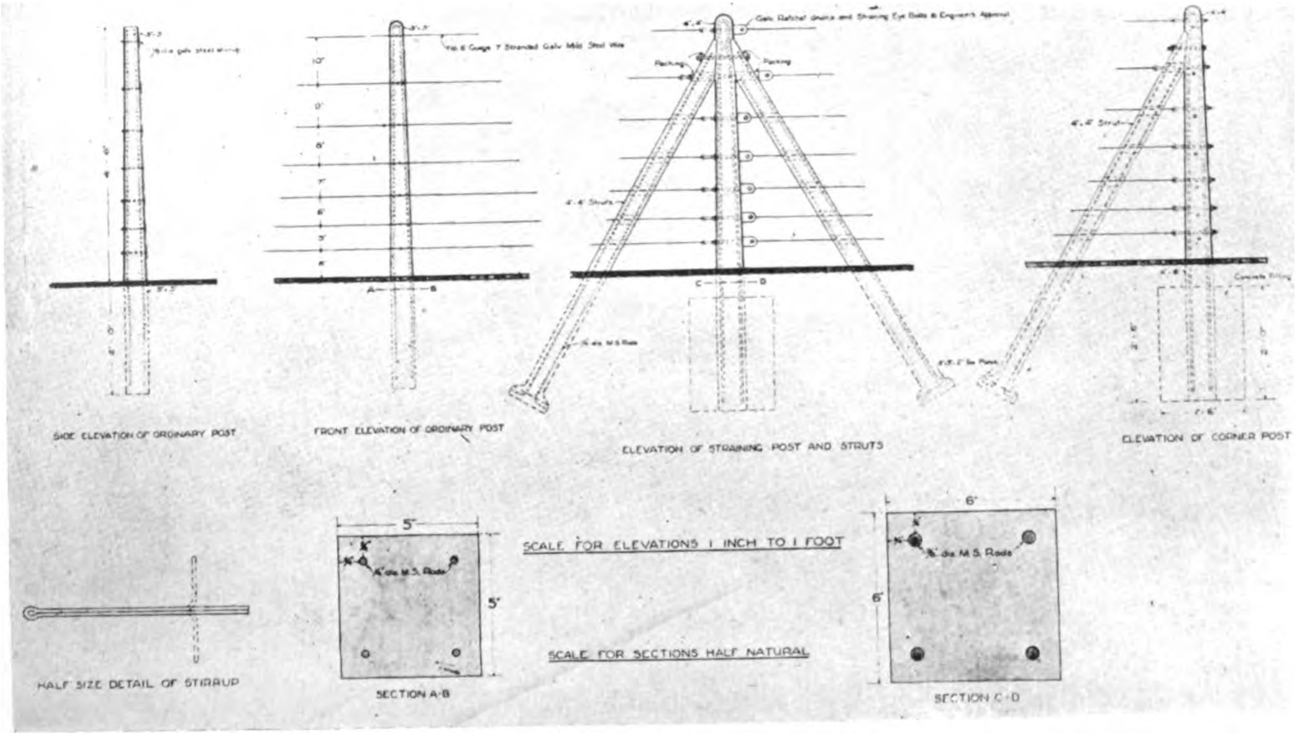
	By Weight %.
Passing 10-mesh sieve and rejected by 30-mesh sieve	55
Passing 30-mesh sieve and rejected by 80-mesh sieve	30
Passing 80-mesh sieve and rejected by 100-mesh sieve	15

The concrete is mixed by batch-type mixers with a capacity of 14 cu. ft. of mixed material, the loading skips having a capacity of 24½ cu. ft.; these machines were specially made by Messrs. Stothert and Pitt, Ltd., to meet Mr. Robinson's requirements that the boom should be designed so that it could be swung round to an angle of 60 deg. to the kerb line, and also with regard to the discharging of a concrete of a dry consistency.

Not only is the plant up-to-date and specially suitable for the work, the layout and organisation for getting the materials to the site of the concreting operations carefully thought out, so that the work goes on smoothly with a minimum of labour and an absence of delay, but the latest teachings of leading authorities on the making of the best concrete are being put into practice on this job. One of the features most noted and commented on by those who have seen many other concrete roads laid in this country is the comparative dryness of the concrete as it is laid. The quantity of water used in mixing the concrete, which varies and depends upon atmospheric conditions and the quantity of water present in the sand and aggregate, is as near as practically possible an amount equivalent to 25 per cent. by weight of the cement used in the mix, or between 2·5 per cent. and 3 per cent. of the total quantity of material used in the mix. When the sand and aggregate are saturated with water to such an extent that a slight "sweat" appears when the concrete is punned into position it is found it is not necessary to add any water


Rods 20'0" and 17'3" long alternately
Face of Kerb
All rods to overlap 9" at joints
Every third rod at joints to be wired together with mild steel wire No. 10 SWG

Kingston By-Pass Road: Plan of Reinforcement, Types Nos. 2, 3 and 4.


SIDE ELEVATION OF ORDINARY POST
FRONT ELEVATION OF ORDINARY POST
No 6 Gauge 7 Stranded Galv Mild Steel Wire
10"
A
B
ELEVATION OF STRAINING POST AND STRUTS
Galv Ratchet Winders and Straining Eye Bolts to Engineer's Approval
Packing
Packing
4" × 4" Struts
C
D
ELEVATION OF CORNER POST
4" × 4" Strut
Concrete Filling
HALF SIZE DETAIL OF STIRRUP
SECTION A-B
5"
5"
SCALE FOR ELEVATIONS 1 INCH TO 1 FOOT
SCALE FOR SECTIONS HALF NATURAL
SECTION C-D
6"
6"
M.S. Rods

KINGSTON BY-PASS ROAD: DETAILS OF CONCRETE FENCING.

to the mix; whatever may be the doubts of those who have become accustomed to seeing much wetter mixtures used the results on this road justify the small amount of mixing water; sections of bays which have hardened show that the concrete is absolutely dense and so firmly is it bound together that it is impossible to dislodge with a hammer the stones showing on the surface.

The concrete is laid in bays the full width of the road by 14 ft. in length, on the alternate bay system with the joints between the bays at an angle of 60 deg. from the kerb. In addition to reducing the liability of damage to the edges of the bays by ensuring that traffic will strike them at a more acute or obtuse angle than a right angle, and also to obviate two-wheel loads of any vehicle striking the joint at the same time, thus reducing the stress along the bay, it is also anticipated that this method of laying the bays at an angle of 60 deg. will reduce the resistance of the concrete to expansion and contraction, and thus assist in eliminating any tendency to bulge and cracks due to expansion.

In order to ensure that the two layers of concrete are laid to the specified depth, a simple method of screeding, which works well in practice, is adopted. Before placing any of the concrete, bolts are driven into the prepared sub-grade where the edges of the bay will come, one at each side of the road and one in the middle. A board six inches in depth, with holes already bored, is then slotted edgewise on the bolts, thus forming the shuttering for the edges of the lower course. After the first course is laid to the level of these boards, other boards, two inches in depth, are slotted on the bolts in the same way, forming the shuttering for the edges of the top course and a screed for levelling the surface of the road.

The reinforcement is wired up into mats on the site, and placed top and bottom of the road; that is, 1½ in. from the bottom and 1½ in. from the top. In order to ensure equal settlement of contiguous bays in the event of settlement taking place, as is very probable on filled ground, the reinforcement is left projecting about 1 ft. from the edges of the bays laid first, and is kept in position by passing the longitudinal bars through holes made for the purpose in the transverse side forms. The top course in each bay is laid immediately after the lower course in order that there shall be no danger of bad adhesion owing to the setting of the lower course. As it is dumped on the road bed from the mixer, the concrete is spread and tamped by hand.

With n 24 hours of the concrete being placed the surface is brushed with stiff brooms to remove all scum, and is then immediately covered with a layer, 3 in. thick, of soil, which is kept damp with water for at least 28 days.

A period of not less than 14 days is allowed before the intermediate bays are concreted. The transverse forms are then removed, and the bays filled in in the same way as the first bays, with the exception that the reinforcement is joined on to the projecting ends of the reinforcement in the first bays instead of having the ends of its longitudinal rods passed through the transverse forms.

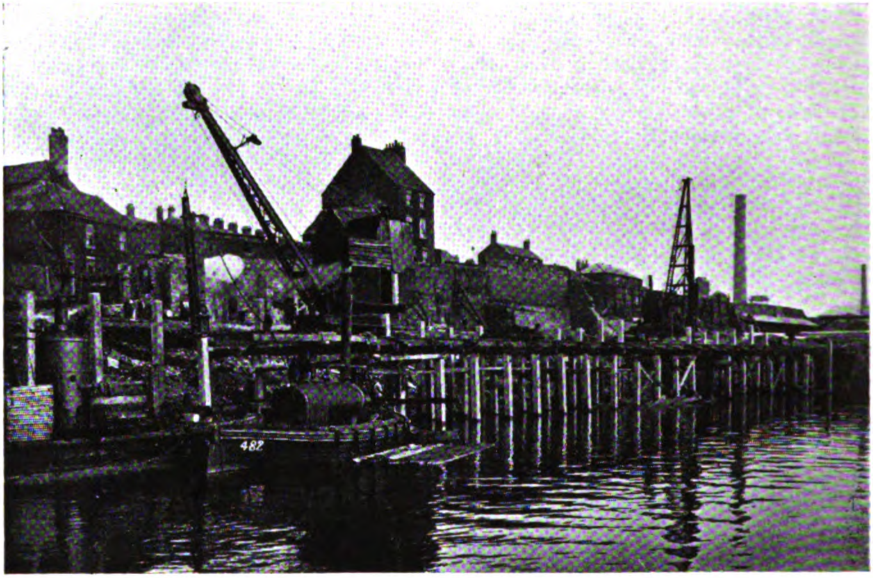
Several bridges, all in reinforced concrete, are to be built to carry the new road over rivers, railways and existing roads, a reinforced concrete bridge over the Hogsmill River having been already completed.

The whole of the kerbs for the road are to be in reinforced concrete, made on the site in special steel moulds which are vibrated whilst the concrete is being filled into them.

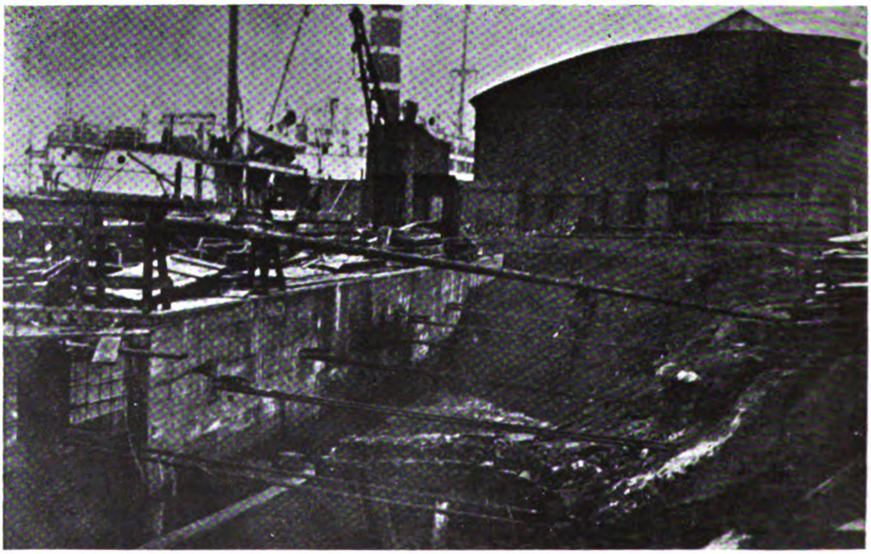
The permanent fencing is also in reinforced concrete, the posts being spaced 9 ft. apart, and having seven lines of galvanised wire clipped to them.

None of the gulley frames are to be placed in the carriageway itself, advantage being taken of the spare land to place them at the side of the road so that they may easily be set back when the carriageway is widened in the future.

The new Kingston By-pass is a road which will amply repay an inspection by all concerned in the provision of better roads. Mr. Robinson has evidently given much thought to the subject of the concrete road, and his careful attention to detail coupled with a thorough knowledge of the material in which he is working have resulted in what will certainly be one of the best all-concrete roads so far laid in this country. A word must also be said for the contractors, Messrs. Stewart and McDonnell, who have the advantage of a wide experience of Canadian practice in laying concrete roads.



General View: Showing Special Gantry from which the Reinforced Concrete Piles were Driven.



Back of Quay: Showing Portion of Curtain Wall and Steel Tie-Rods running back to the Anchorages.

REINFORCED CONCRETE WHARF AT NEWCASTLE-ON-TYNE.

REINFORCED CONCRETE WHARF AT NEWCASTLE.

THE new wharf on the Tyne, east of Ouseburn, illustrated herewith, forms an extension of the Norway Wharf used by the Bergen and Newcastle steamers. It is known as Quayside No. 22, and is situated just below and to the east of the outfall of the Ouseburn. The wharf has been built to the design of Mr. W. J. Steele, D.S.O., M.Inst.C.E., Chief Engineer to the Newcastle-on-Tyne Corporation. Messrs. Mouchel & Partners were responsible for the reinforced concrete details, and Messrs. Kirk & Randall, Ltd., of 146/7 Grosvenor Road, S.W.1, were the contractors for the construction.

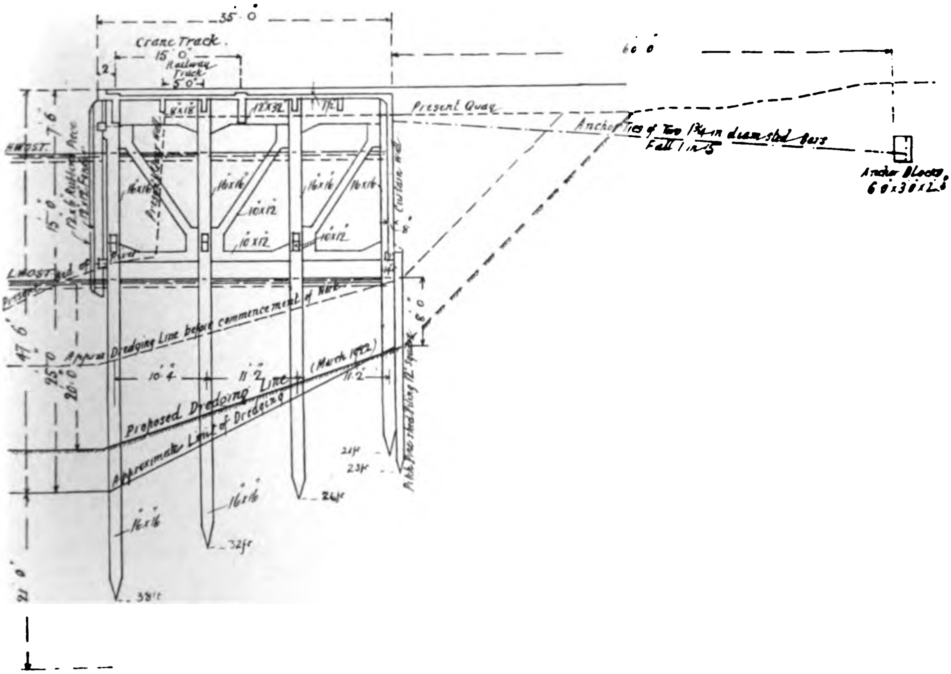
The wharf is carried on reinforced concrete piles, spaced 12 ft. longitudinally, and 10 ft. transversely. The piles have a steel reinforcement of 11 lbs. per cu. ft., and are shod with chilled cast-iron shoes weighing 80 lbs. The piles were driven to just above L.W.S.T. and carried the columns and diagonals forming the superstructure which supported the reinforced concrete deck, and also the curtain wall holding the bank at the back of the wharf.

The bank is supported by creosoted pitch pine sheet piling extending the entire length at the back of the wharf, and the curtain wall already referred to.

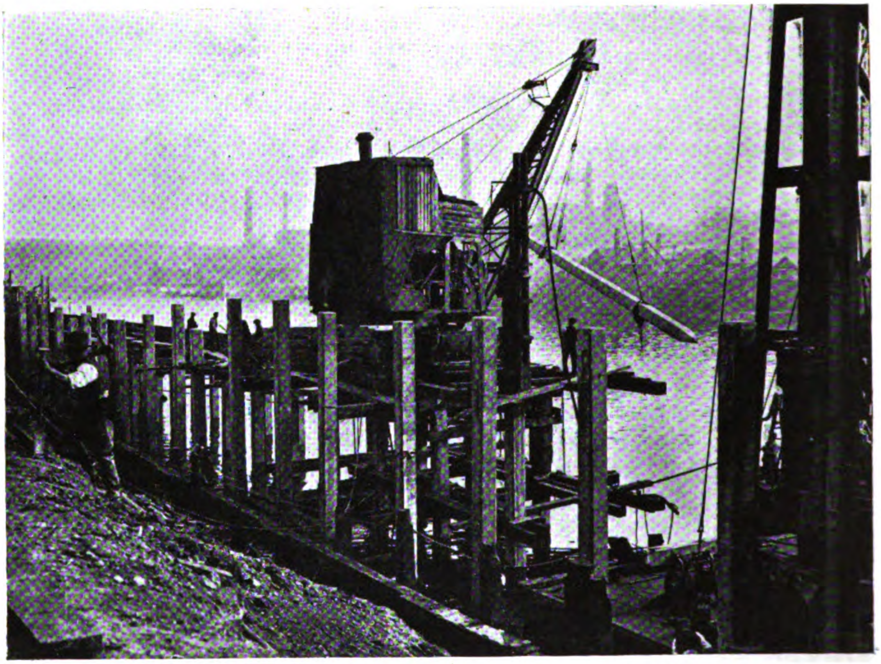
The wharf is anchored by means of heavy reinforced-concrete blocks sunk in the bank and connected to these with steel tie rods laid in glazed earthenware troughs. The rods are run in with bitumen as a protection against corrosion.

The piles were constructed on a piece of land in continuation of the wharf where a suitable floor had been prepared and equipped with the necessary plant for assembling the steel skeletons and for the speedy and cheap distribution of concrete and the subsequent handling and transport of the piles to the site.

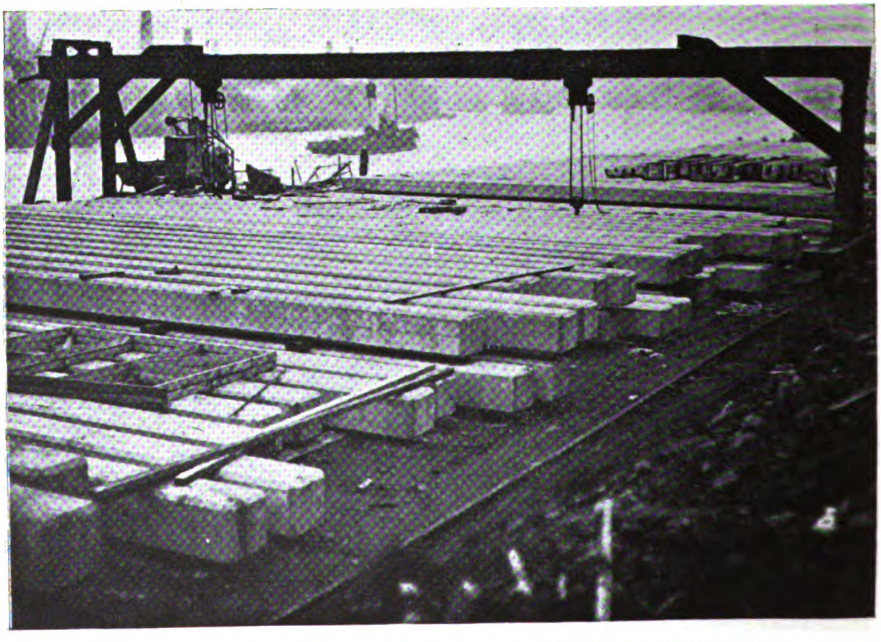
A feature of the construction was the large amount of pre-cast work introduced in the form of walings and braces in order to reduce the work to be carried out *in situ* between the limits of High and Low Water. A special site was provided



CROSS SECTION.



Crane Pitching Reinforced Concrete Pile from Gantry.



The Pile Yard: Showing Special Straddler used for Making and Lifting Piles.

REINFORCED CONCRETE WHARF AT NEWCASTLE-ON-TYNE.

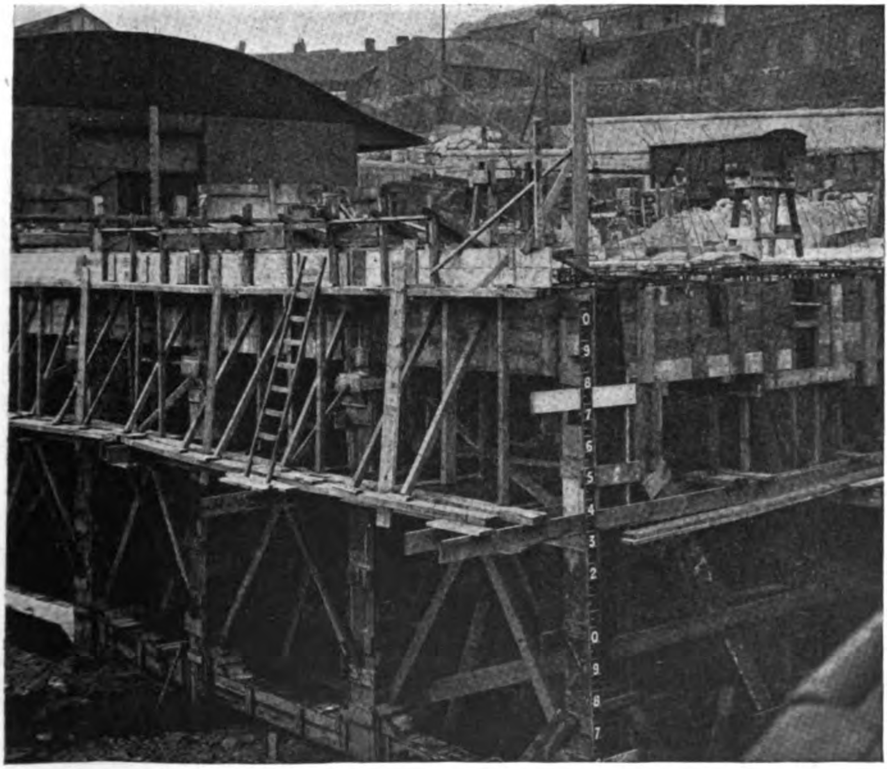
for the preparation of the pre-cast pieces.

The method of driving the piles was to dredge a level platform at 2 ft. above Low Water. Upon this a subcarriage travelling upon three lines of rails was erected, which carried the gear for lifting and driving the piles. Great difficulty was encountered in securing the penetration of the piles through the boulder clay which constitutes the formation of the river bank at this point, and boring with steel casings was resorted to in order to ensure an adequate penetration.

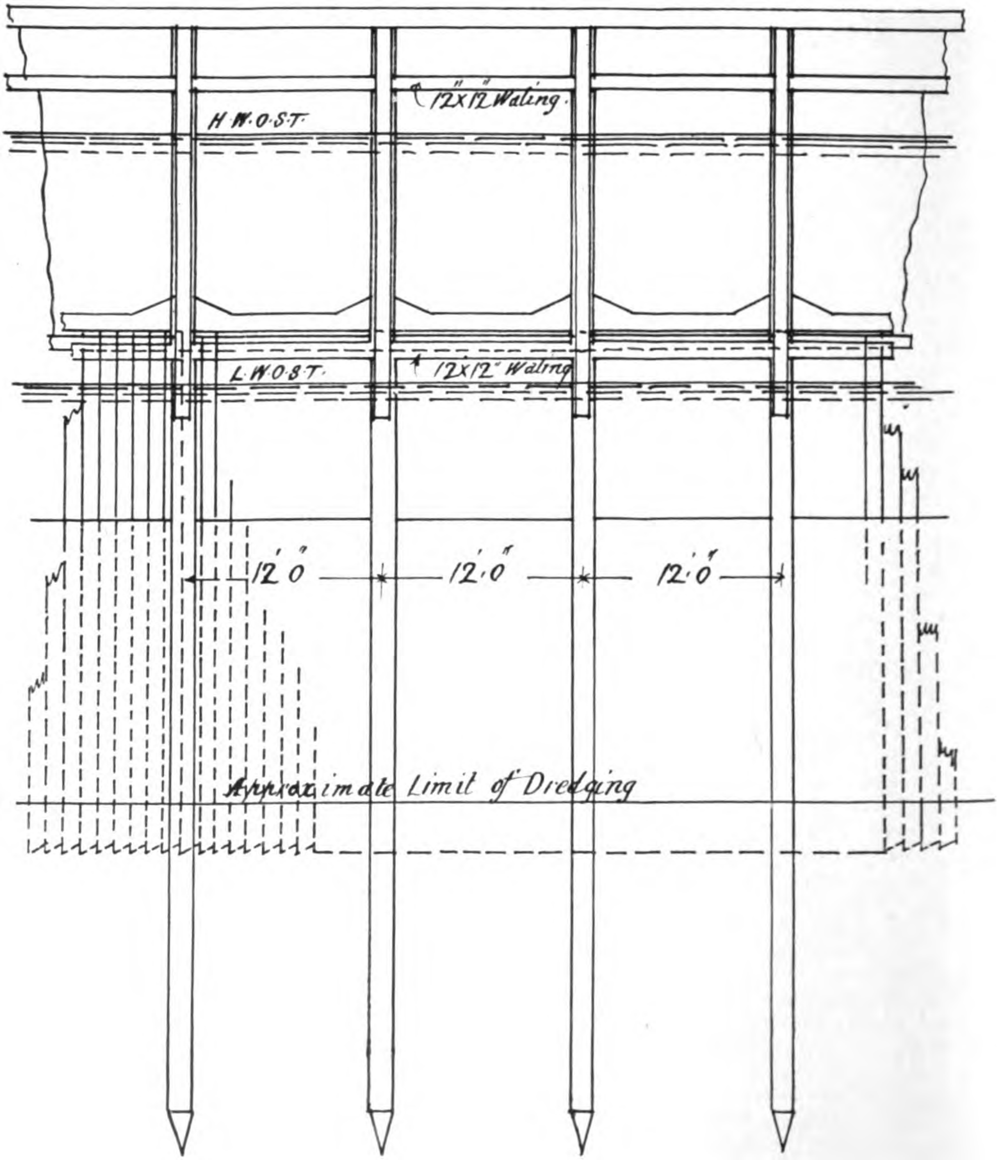
This procedure resulted in some delay to the progress of the work, and in order to compensate for this a steel gantry was constructed to enable the work of pile driving to be carried on simultaneously at different points, further dredging being also resorted to to reduce the resistance to penetration. Progress was further augmented by means of a pile barge moored in the river, which was used to drive the front row of piles and proved of great assistance in this portion of the work.

As soon as a certain length of wharf piles had been driven, work on the timber sheet piling at the rear of the wharf was commenced and carried on concurrently with the piling for the wharf itself.

Eight bays of piles having been driven down to slightly above level of L.W.S.T. and the pile heads being stripped, the work of erecting the superstructure was commenced. This work consisted in erecting the boxes forming the shuttering of the columns on the pile heads, these being in turn supported by temporary timber walings bolted to the piles as closely as possible to Low Water level, the steel reinforcements being secured inside the column boxes by means of special clips. The pre-cast horizontal walings and diagonal struts were subsequently threaded into position and



Shuttering for Superstructure.



Part Front Elevation.

REINFORCED CONCRETE WHARF AT NEWCASTLE-ON-TYNE.

supported. This then formed the first lift of the superstructure, and was carried along for four or five bays.

The next step was to erect the shuttering with the steel reinforcement of the beams carrying the deck of the wharf, and connect this with the head of the column boxes, after which the concreting could be brought up to the underside of the main beams.

The final stage was reached when the shuttering for the floor of the platform of the wharf was constructed and the steel skeleton laid in position. This work was concreted in lengths of one bay of 12 ft., the concreting being carried from the centre of one bay to the centre of the next.

The curtain wall on the land side of the wharf was carried up step by step with the column erected upon the pile heads until it reached the platform level, where it forms a continuous wall helping to retain the bank.

One side of the transit sheds was founded on one side on the wharf, and the other side on deep foundations placed in the bank.

A new approach road has been constructed from the west end, this part of the work being carried out by the Corporation with direct labour. The transit sheds have been constructed by Messrs. Wright Anderson of Gateshead, to the design of Mr. W. J. Steele, D.S.O., M.Inst.C.E.

BUILDING AND DESIGN IN THE FUTURE.

In the course of an article in a recent issue of *The Builder*, Mr. J. Hembrow says: " It is fair to say that compared with other great industries the art of building is backward; we are still in a large measure doing as we have done for centuries. The intense conservatism of the architect is the likely explanation of this startling fact. But even when the architect is of that hopeless mental attitude which asserts that as in forty years' experience a certain way was found best a change must not be contemplated, he will have brought home to him the fact that his having done the thing one way for forty years is a sure sign that it is time it should be done differently. The solution of building problems will probably be found when we are forced to utilise labour in such a way that more cube is produced in a given period of time, and this will inevitably affect design. The inventive mind is already moving in this direction, and reinforced concrete may well come into its own.

" Ferro-concrete has many advantages in this direction, and in addition allows us greater floor space for the same strength. This is a considerable merit where ground rents are high, or where tall buildings are built. How many of us have really considered this comparatively new medium with the seriousness it deserves? The old objection of our youth that ' the world had not enough experience of it ' has no force now—men with more courage have answered it in a practical way. We have remarked the increasing beauty in the reinforced concrete structure. Some of the structures have already attained a beauty of their own. As our knowledge of the medium increases and it is more broadly adopted, it will undoubtedly affect design profoundly, if a new period in design or an almost entirely new style is not evolved. It is surely something to dream of when we consider the new forms which will insinuate themselves inevitably into our buildings as our use of this material grows. We shall perhaps be able to dispense with that deception, the modern stone front, which is merely a curtain of sham respectability hung over the crude hideousness of steel.

" Then we have an inheritance of the ages of habit in the form of bricks as a building unit. This method of building will go by the board with time, except for special work. With scarcity of labour added to costliness it is economically unsound to construct a wall in such a laborious way. Habit and lethargy have militated against the adoption of a method more in keeping with the twentieth century, but it is mostly sheer laziness which has left the many clever methods which are being devised and improved every day to the enthusiasm and self-sacrifice of a few.

" Design at the moment is transitional. It is already apparent that form is changing and that the older order is losing ground in the battle against the new and vigorous. There is already one concrete façade in the heart of the West End of London; there will be many more."

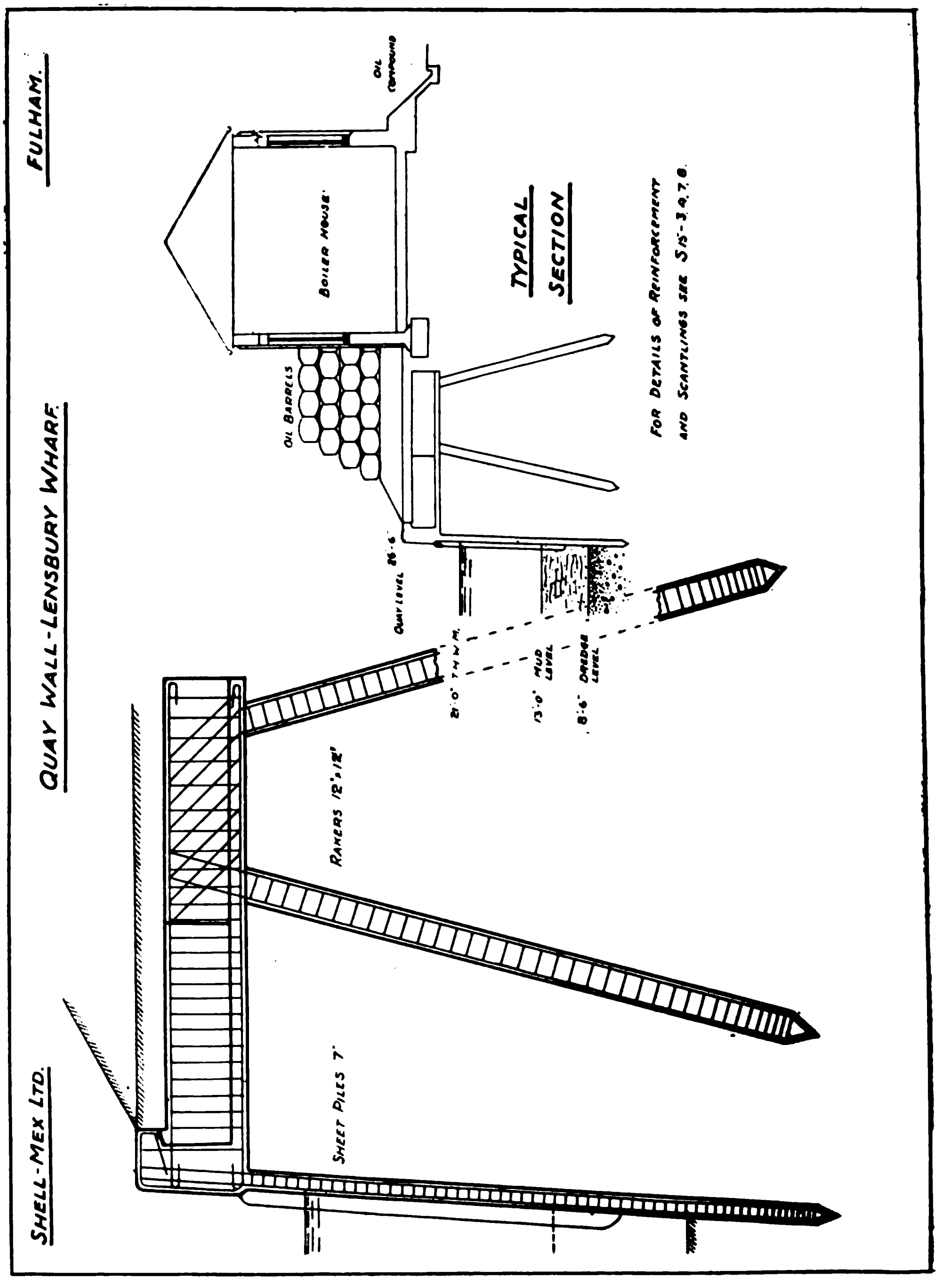


FIG. 1.—REINFORCED CONCRETE QUAY WALL AT FULHAM.

QUAY WALL AT FULHAM.

A REINFORCED concrete quay wall, designed on lines that are comparatively new in this country, has been completed and in use for some time at the Lensbury Fuel Oil Establishment of Messrs. Shell-Mex, Ltd. The construction makes use of a weighted slab and inclined piles to produce an extremely rigid and stable structure, which at the same time is claimed to be the cheapest possible form of quay wall construction. The principle underlying the design was described in this journal some time ago, in an article by Mr. R. N. Stroyer, who first introduced the type of construction in this country a number of years ago, and was responsible for the design of the quay wall at Fulham now described.

A typical section of the quay wall at Fulham is shown in *Fig.* 1, from which it will be seen that the depth from the coping to the tip of the sheet piles is about 22 ft., giving a barge-berth with 12 ft. of water at high tide while for a short period at low tide the foreshore is dry. A heavy surcharge is imposed on the quay wall by stacks of oil barrels, the wharf being used for storage and for discharging fuel oil into oil barges; for the latter purpose a pump-house is installed at the far end of the wharf, while the boiler houses are situated in the middle, just behind the wharf construction.

The sheet piling is 7 in. thick, while the rakers, both compression and tension piles, are 12 in. square. In the calculation of the sheet piles certain conditions of earth pressure have to be taken into account, peculiar to this type of construction; the circumstances governing the dimensioning of the sheet piles are as yet but little explored experimentally, although it is general knowledge among a wide circle of engineers that the earth pressure in these cases follows rules quite different from those usually assumed; it may be mentioned that the scantlings of the sheet pile itself have a certain bearing upon the magnitude of the pressure from the fill behind it.

The designer has made a special study of these circumstances. The first quay wall of this type in this country was built at Lowestoft in 1917, while the wharf just described is the first in the Thames and is to be followed shortly by one of very much larger dimensions at Purfleet, which will be one of the most important wharves on the Thames, having a depth of water of about 37 ft., while the height from coping to firm bottom is about 60 ft.

A feature of the Lensbury wharf was the use of quick-hardening cement for a

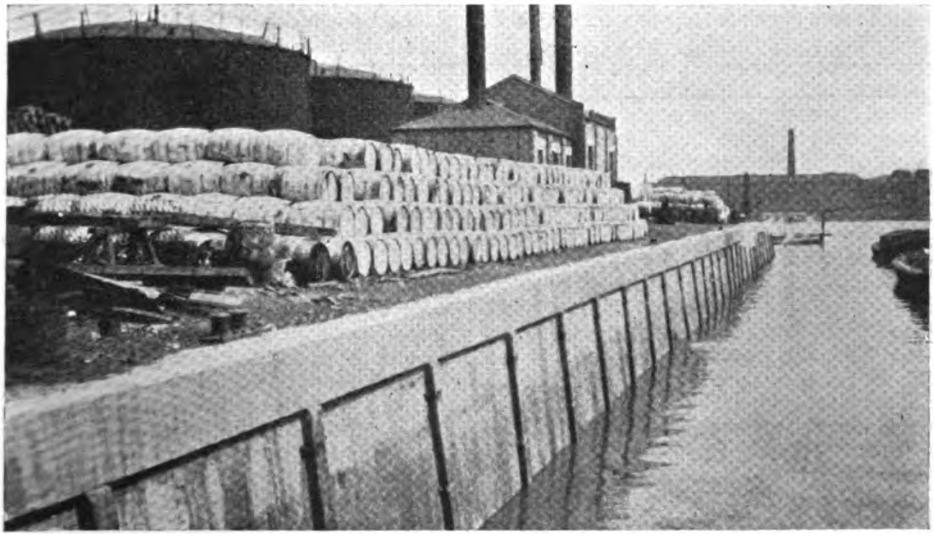


FIG. 2.—REINFORCED CONCRETE QUAY WALL AT FULHAM.

number of the piles in order to expedite the progress of the work; these piles were driven in the usual manner 3–4 days after having been cast. Some difficulty was experienced by the contractors, Messrs. J. Perkins and Son, Bristol, in executing the new work owing to the line of the new wharf coinciding with that of the old timber wharf, which latter had to be demolished as the new work proceeded, but a method was devised by which the old king piles were made to serve as a pile-driving gantry until a sufficient number of sheet piles had been driven, when the king piles were extracted and the gaps filled. A view of the finished wharf is shown in *Fig.* 2.

BOOK REVIEW.

Lime and Magnesia. By N. V. S. Knibbs. London: Ernest Benn, Ltd. Pp. 306. Price 30/- net.

LIME or magnesia are comprised in practically all the binding materials used in constructional work, and a book dealing with the chemistry, manufacture, and uses of lime and magnesia is therefore of interest to the constructional engineer. Such a comprehensive treatise as this upon the subject in the English language had not previously existed, and the volume should fill the need for a reference book for the industries manufacturing and using lime and magnesia.

The first section of the book, dealing with the chemistry of lime and magnesia, is very complete and provides a convenient collection of all the known chemical and physical data concerning the two materials and also their carbonates and hydrates. The second section is concerned with manufacturing processes, not only from a practical standpoint but also from the theoretical point of view, the chapter on the thermal efficiency of lime-burning being particularly interesting. A fuel consumption of 20 per cent. would be regarded by most lime burners as satisfactory, but the author shows that even this represents an efficiency of only 55 per cent., the remaining 45 per cent. of the fuel being wasted. A welcome feature is the description of methods of mechanical hydration or slaking of lime, in connection with which it is stated that a good mechanical hydrator does the work better than the best workman and reduces the labour cost very considerably. It is indeed anomalous that in these days of mechanical development lime should be supplied by the manufacturer in the lump form, thus placing upon the builder and other users the obligation to slake the lime, which is done in many cases by inefficient hand methods and always at a higher cost than the slaking could be done mechanically by the manufacturers.

The author has drawn largely from American sources of information. It is regrettable, however, that Continental methods of production are not given more attention in the book because in France particularly the lime industry is a very important one and approaches that of Portland cement in its productive capacity. Moreover, the manufacture of hydrated grey lime has in France been developed to such a degree that it is sold on specification for strength and other properties, and there should be scope for similar development in this country.

The third section of the book deals with the uses of lime and magnesia for constructional work, agriculture and other purposes. Magnesia is largely used as an oxychloride cement for flooring and stucco work.

The lime industry has been neglected both in literature and in practice by the scientist and, in consequence, methods of production of lime are still employed that were in operation centuries ago. Under present conditions, the British builder buys lime in the lump form to which no standard of quality can be applied, he has to slake the lime by laborious and inefficient hand methods, when he is liable to discover that some of the material is underburned and useless, while other material is overburned, and unless allowed a long time to slake will "blow" and expand in constructional work. When this procedure is compared with the growing American and Continental practice of supplying lime in hydrated powder form fit for immediate use, packed in bags and with a guarantee of certain qualities, it will be seen that there are great possibilities of the British lime industry developing in the same direction.

REINFORCED CONCRETE SCRUBBERS FOR GAS PRODUCER PLANT.

The average life of a gas scrubber constructed of mild steel plate rarely exceeds eight to ten years, and where it is necessary to use water which has a corrosive effect for scrubbing the life is often considerably less. With the object of obtaining a very much longer life and reduction in the cost of maintenance, the construction of these scrubbers in reinforced concrete has been undertaken with excellent results.

A number of complete plants have been erected by the Associated Portland Cement Manufacturers, Ltd., for use at their various works, some of which have been in operation for several years without it being necessary to carry out any repairs ; and there appears to be no reason why these scrubbers should not last indefinitely as there is little which can deteriorate.

It will be seen from *Fig.* 1 that a scrubber consists of a number of similar spigoted and socketed sections placed one above the other, the number of sections, of course, depending on the height and diameter of the scrubber required.

Some of the sections are provided with openings in the side for inlet and outlet pipe connections, cleaning doors, etc. All such openings are formed by a curved cast-iron frame having a double flange between which the concrete is placed. Where it is necessary to fix brackets on the inside of the scrubber, cast-iron bosses having double flanges are cast in the section. Bolts are passed through the cored holes provided in the bosses, and in this way the brackets are secured.

The reason for adopting this method of construction will be clear if reference is made to *Fig.* 2, which shows in section the type of mould that is employed. This mould consists of a wooden base to which are secured a core made in three sections, and the shell, which is also made in three sections. The use of curved frames enables them to be placed in almost any position in the mould, and makes it possible for one mould to be used for a variety of scrubber sections.

It is necessary to use this form of mould rather carefully, but where this care is exercised it is possible to cast a very large

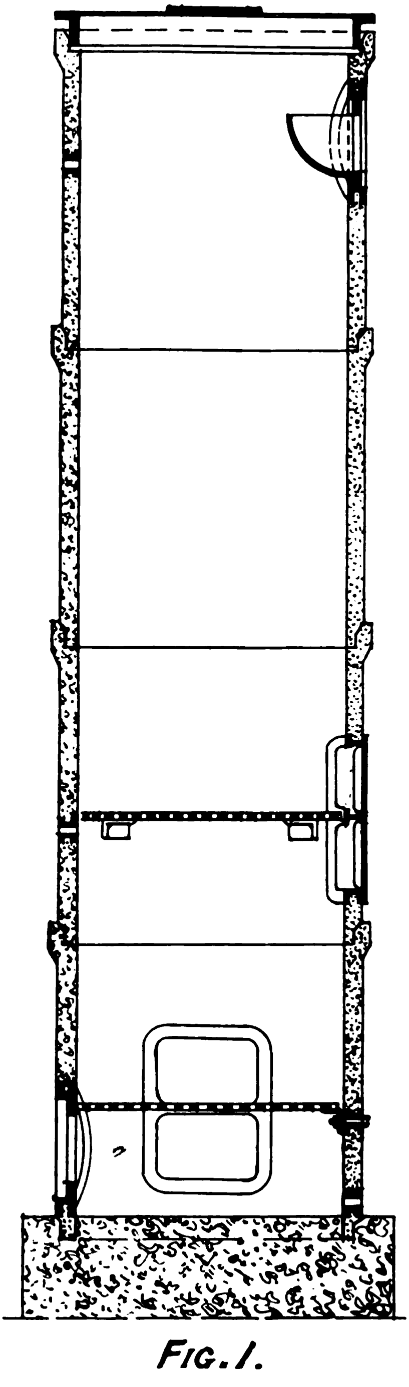


FIG. 1.

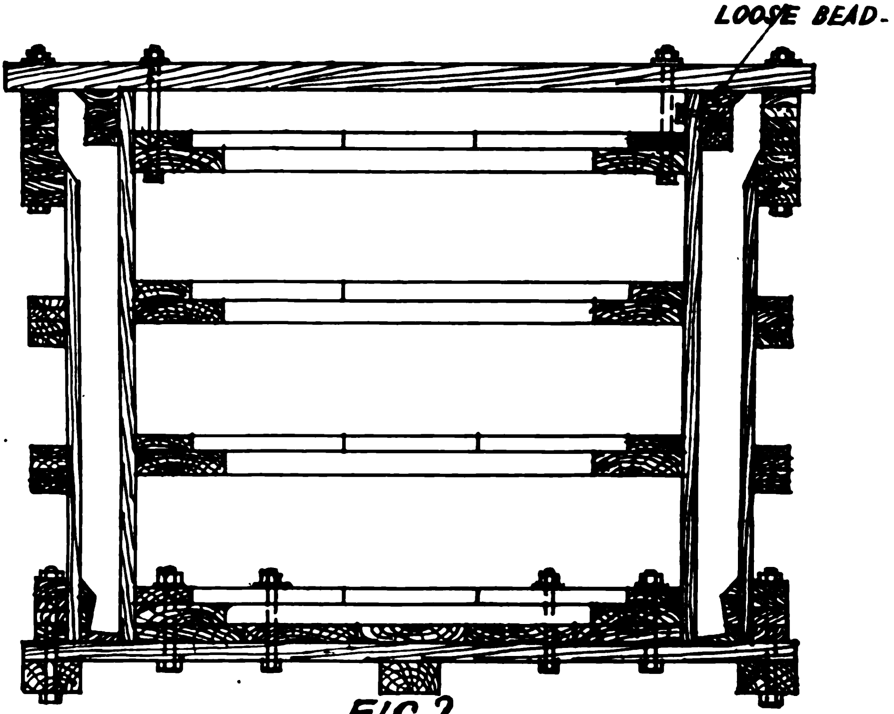


FIG. 2.

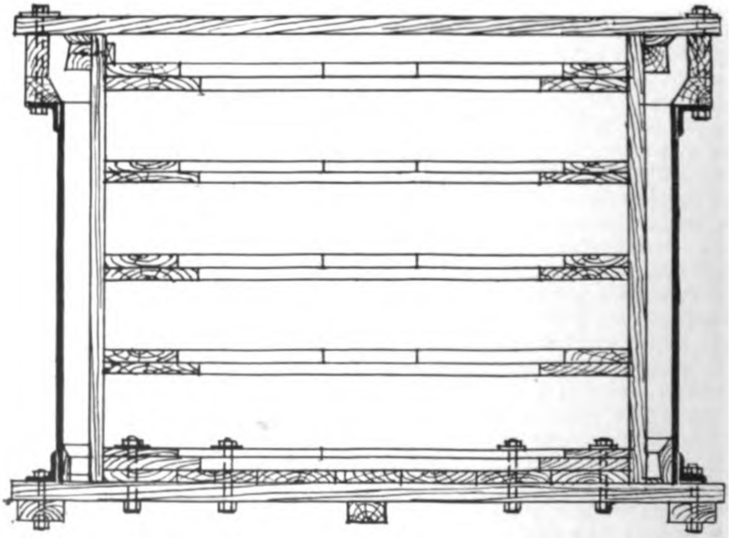


FIG. 3.

REINFORCED CONCRETE SCRUBBERS FOR GAS PRODUCER PLANT.

number of sections from one mould. It has been found that the shell is more liable to get out of shape than the core, and for this reason, in later designs, the shell has been constructed partly in mild steel as indicated in *Fig*. 3. It has been found desirable to continue to construct the core of wood, as will be explained later.

The procedure in the case of a section having a large number of frames in it is as follows :—The base is placed on firm and level ground, and the core erected on it. The position of the various frames is carefully marked on the surface of the core, and each frame is secured in its position by blocks of wood placed inside the frame and screwed to the core. The expanded metal is then bent round, and the necessary openings for the frames cut in it as required. It has been found best to use a "diamond mesh" expanded metal with the long way of the mesh in a vertical direction, as it is then more easily bent to the desired curvature.

Strips of wood are placed in a vertical position, and at a convenient distance from one another, between the core and the expanded metal so as to keep it in the centre of the space between the shell and core. The shell is then placed in position and secured to the base, care being taken that the top of the shell and core are concentric. The mould is then ready for filling.

The concrete, which is mixed rather wet, is made up in the proportion of 3 parts of ⅜-in. sharp washed ballast, 2 parts sharp washed sand, and 1 part of Portland cement. The concrete is then placed in the mould, a little at a time, the mass being "rodded" frequently so as to let out the air and obtain a dense concrete. When the mould has been filled to a depth of, say, 1 ft., the vertical wooden strips placed between the core and the expanded metal are partly withdrawn, and this procedure is continued until the mould is filled to within 6 in. of the top, when they are entirely withdrawn. The bead shown attached to the core in *Figs*. 2 and 3, and which is made in about three sections, is then placed in position and secured from the inside

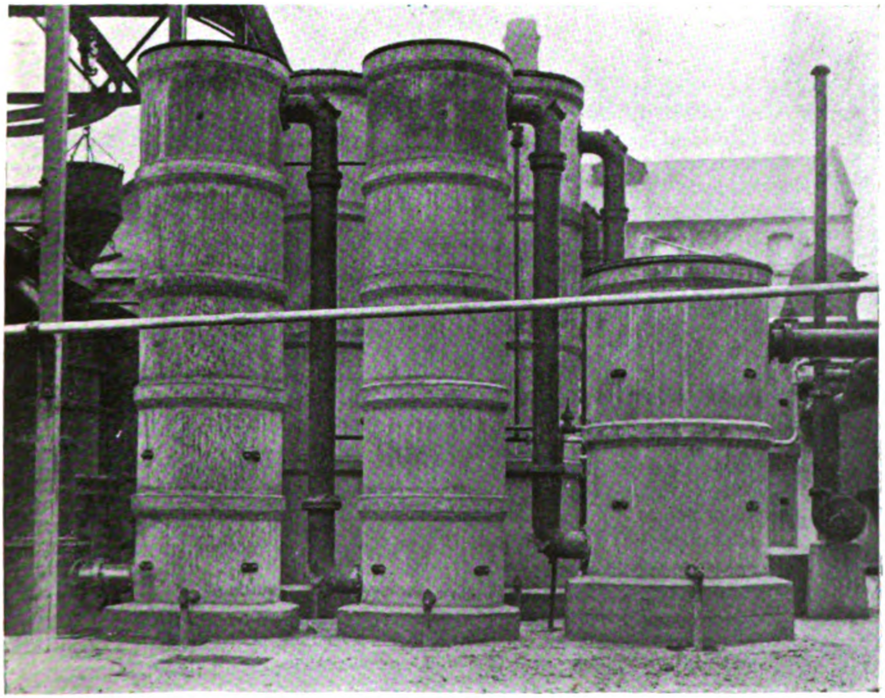


Fig. 4.

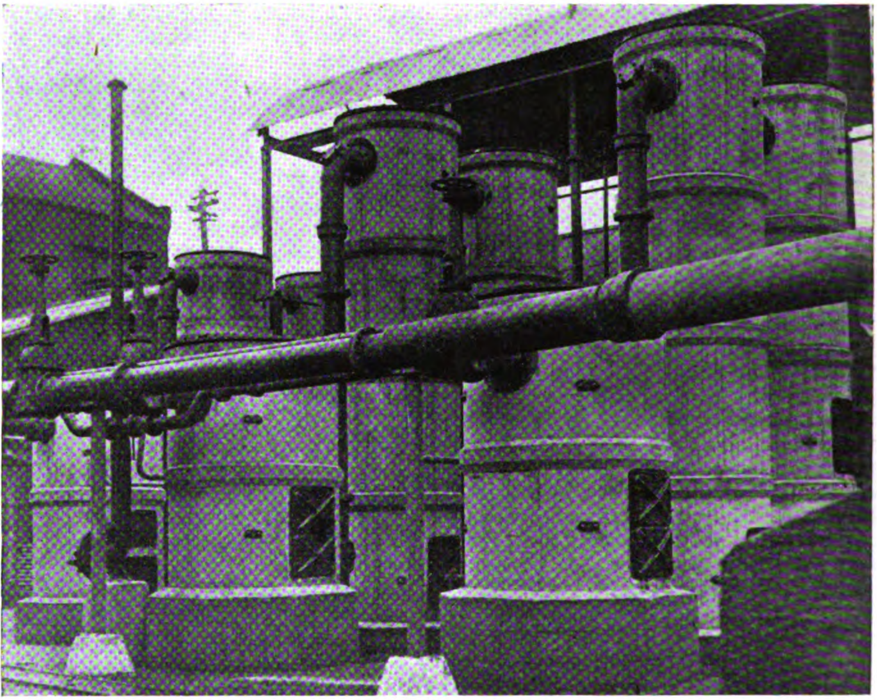


FIG. 5.

of the core by coach screws. This bead then forms the socket of the finished section. The filling of the mould can then be completed, and, when the moisture has mostly risen to the top, the concrete can be trowelled off so as to give a good finish to the top of the socket.

The length of time which must elapse before the mould can be removed depends to a large extent upon the weather conditions, but from 3 to 4 days is usually sufficient. The core is first collapsed, after which the bead can be removed. The shell is then taken off, and the concrete section may be carefully removed to a place where it is allowed to harden off thoroughly.

When erecting the sections on the site it is advisable to position and line-up the first section and grout it up on its foundation. The other section can then be placed in position and all the joints grouted up. Alternatively, the socket of the first section can be filled with fairly stiff cement mortar, and, when the section above is lowered into position, the mortar is squeezed out and can then be immediately finished off. The former method is perhaps the better, as it enables the erector to make quite sure that everything is right before the sections are finally jointed to one another.

Referring again to *Fig.* 1, it will be seen that the top of the scrubber is formed by a mild steel plate bolted to a circular angle section cast-iron ring which is grouted into the socket of the top section. As a precaution against explosions which might occur, a hole is cut in the cover of the scrubber over which a thin rubber disc is secured. Should any explosions occur this disc will immediately split and release the pressure. *Fig.* 4 shows a plant consisting of two wet scrubbers and one dry scruber. The bosses to which the angles are secured for supporting the internal grids are clearly visible. *Fig.* 5 shows a general arrangement of three of these units, and here the method of attaching the pipes, doors, etc., can clearly be seen. *Fig.* 6 is a slightly different view of the same plant, and in the foreground will be noticed the gas main to the engine, which is also made of reinforced concrete

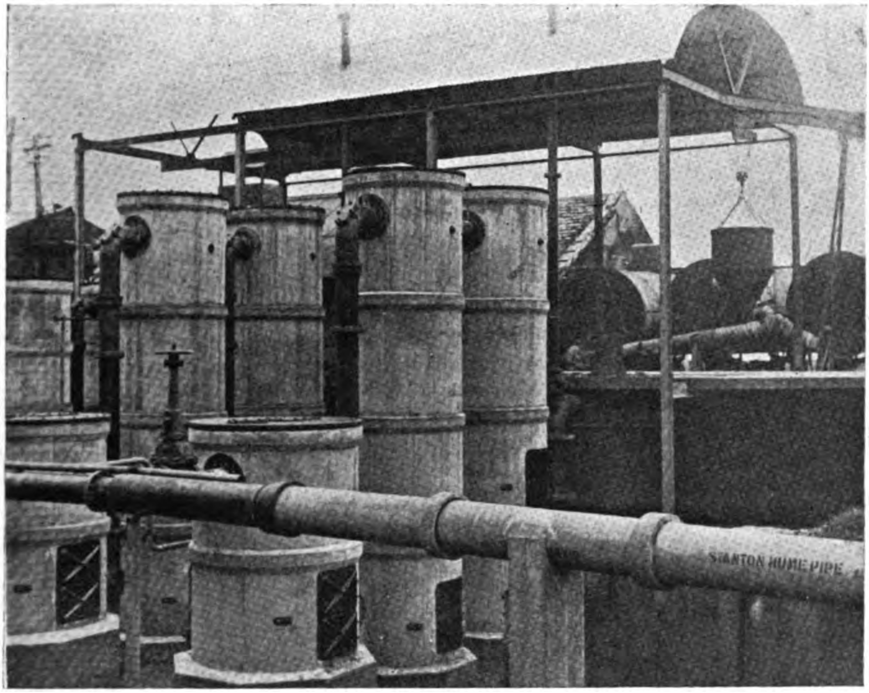
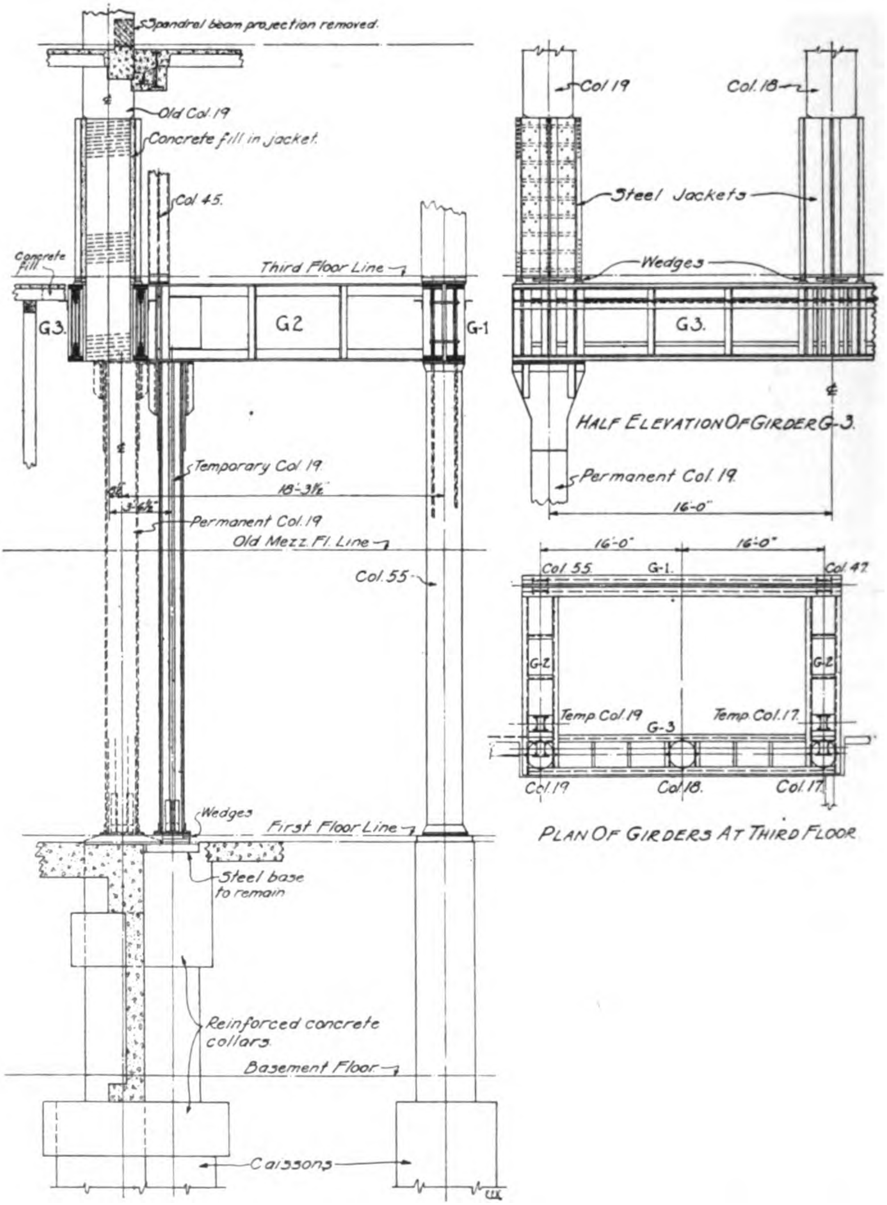


FIG. 6.

and is supported at convenient points by mass concrete piers. It is also interesting to note that the building in the background which covers the producers is covered with corrugated cement sheeting.



Details of Foundations, the New Permanent and Temporary Steelwork, and Method of Supporting Old Reinforced Concrete Columns.

SHORING AND REMOVING HEAVILY-LOADED COLUMNS. (*See p.* 521.)

SHORING AND REMOVING HEAVILY-LOADED COLUMNS.

An account of the methods adopted for shoring and removing heavily-loaded concrete columns when additions were made to the Exchange National Bank of Tulsa, Oklahoma, is given by Mr. Kenny Johnson in a recent issue of the *American Architect*, from which we take the following:—

At the time that the twelve story building for the Exchange National Bank of Tulsa, Okla., was erected (1916) it was thought that sufficient provision had been made for the future expansion of the business. However, in 1922 it became apparent that the provisions made for expansion were entirely inadequate and that an addition to the building would have to be erected on the rear, or south end, for which an area of 75 by 89 ft. was available.

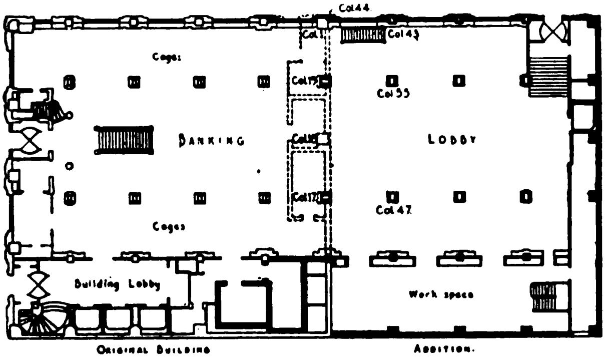
The banking room arrangement, as shown by the plan, indicates in outline the original building, in dotted lines the portions of the original building which obstructed the extension of the banking lobby, and the removal of which was necessary. Particular mention is made of the absence of columns in the banking lobby. One of the owner's requirements was that this 32-ft. wide lobby be extended through the addition, providing a space free from columns.

The original building was of the reinforced concrete skeleton type with the exception of a row of steel columns on each side of the banking lobby. These columns supported girders in the third floor which in turn supported reinforced concrete columns which extended through the upper stories. At the rear end the wall columns were located at regular intervals and they were obstacles in making the extension of the banking lobby as desired. On examination of the plan it is seen that columns 17, 18 and 19 were not so located as to permit a symmetrical treatment of the banking room. They were also of greater size than the finished marble columns in the original banking room space. If column 18 had remained in place it would have stood in the lobby by itself and would have been objectionable.

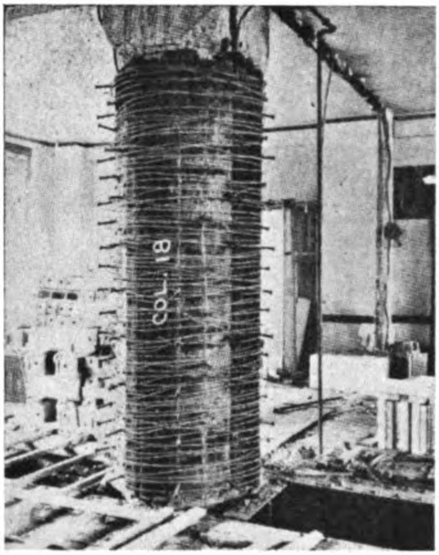
These columns were of the usual spirally reinforced concrete type, having cores 32 in. in diameter. It was necessary to shift the centres of and reduce the size of columns 17 and 19 and to remove column 18 from the first story entirely.

This change made it necessary that three of the four columns in the old rear wall should be shored up and cut off. To support the heavy loads without settlement, foundations would be required equal to the existing foundations. Caissons were built adjacent to columns 17 and 19 to support the temporary shoring columns and to resist the eccentricity resulting from the shifting of columns 17 and 19. The new caissons were bound to the old caissons with reinforced concrete collars built near the top.

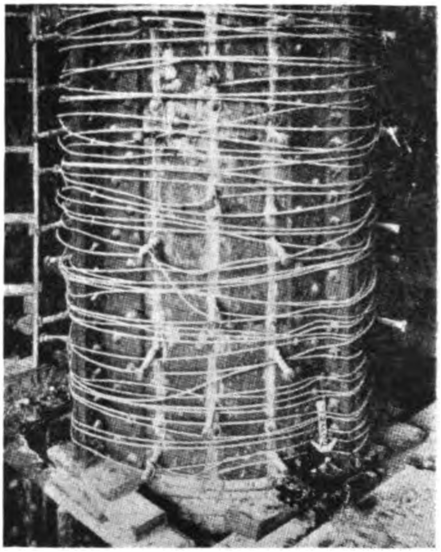
The rearrangement of the girders and columns is shown in the detailed drawings. The temporary columns, 17 and 19, were placed on cast steel plates and wedges for the purpose of adjustment and removal. It is evident that a series



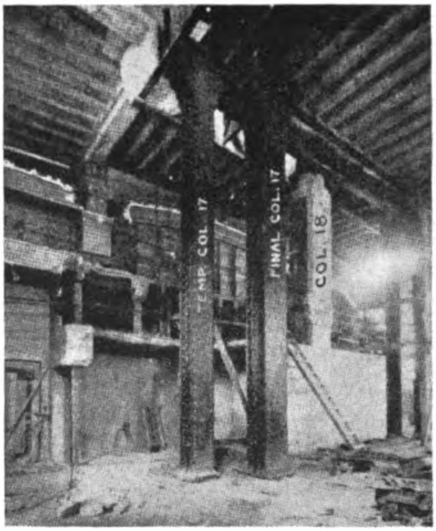
First Floor Plan: Showing Original Work, Work Removed, and the New Addition.



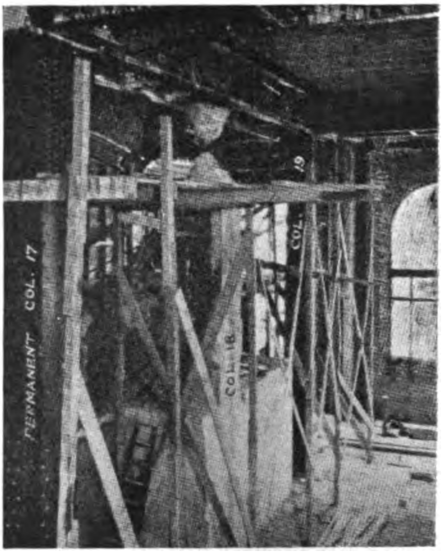
Steel Jacket around Column No. 18 filled with Concrete but not wedged to Girder G3.



Steel Jacket around Column No. 18 wedged down to Girder G3 to produce Deflection; Wedges pinned in place.



Temporary Column supporting the Load before placing Column No. 17.

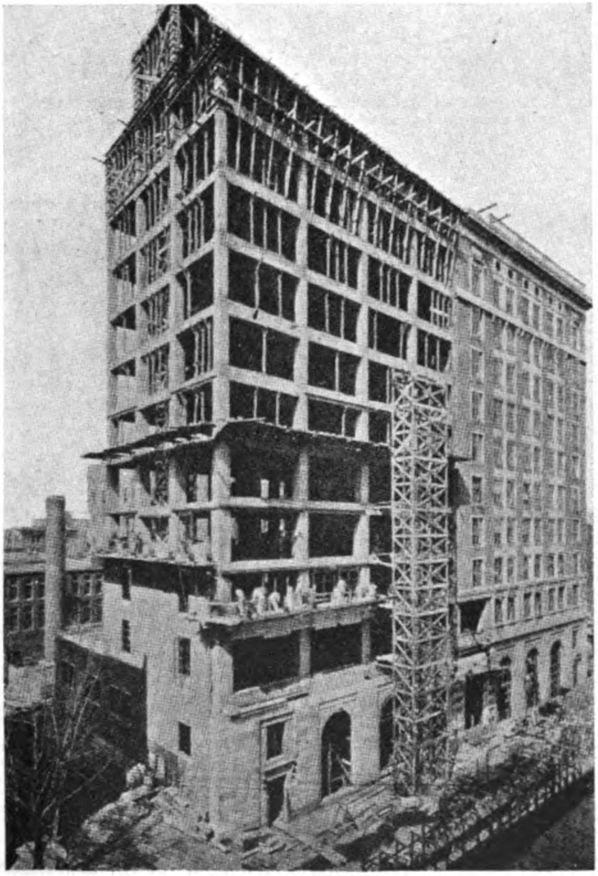


Temporary Columns, Nos. 17 and 19, Removed and Permanent Columns supporting the Load. The Concrete Column has been cut free at top.

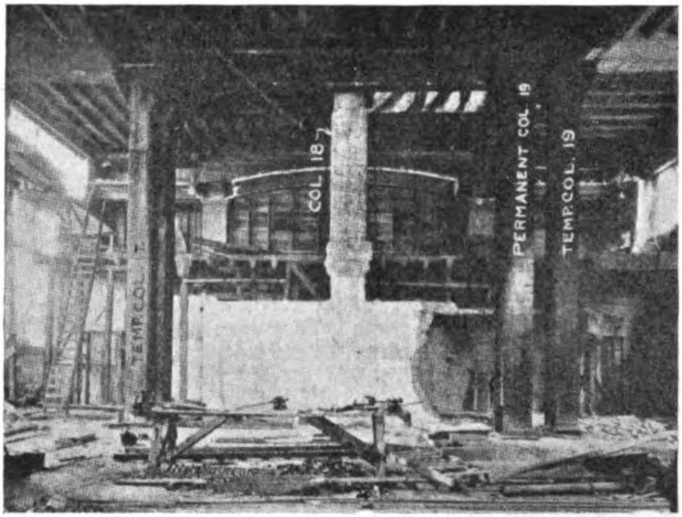
SHORING AND REMOVING HEAVILY-LOADED COLUMNS.

of temporary shoring girders would be required to support the concrete columns above the third floor until some kind of permanent supports was provided. It was finally decided to build in permanently the shoring construction and allow it to remain in place. The most important problem was to make sure that the concrete columns would transmit their loads to the shoring girders. To accomplish this it was decided to strip the concrete columns of their fireproofing in the third story, exposing the spirals, and then to encase the columns in steel jackets; the space between the jackets and the old columns to be filled with concrete proportioned of one part of cement, one part of sand and two parts of gravel crushed to pass a ½ in. ring. These old concrete columns were allowed to carry their own loads until all the structural steelwork was in place and the steel jackets placed in position and filled with concrete, which was then allowed to age for ninety days before the lower portion of them in the first story was removed.

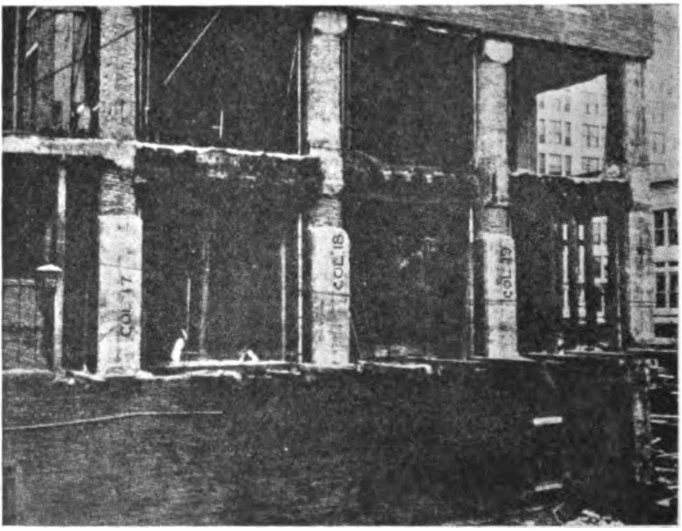
These steel jackets form the basis of the design. Their inside diameter was 36 in. and they were 9 ft. high. The bond stress was calculated on the inside of the jackets at about 40 lbs. per sq. in. and at 45 lbs. per sq. in. on the concrete columns. The jackets were composed of four sections of ½-in. bent steel plates, with vertical angle iron stiffeners for connecting the flanges and bearing lugs. The vertical stiffeners were bolted together with ¾-in. diameter turned bolts inserted in reamed holes. Horizontal



Exterior during Construction.



General View of Assembled Steelwork. Permanent Column No. 17 in Position; Permanent Column No. 19 not in Position; Column No. 18 not Removed.



Columns Nos. 17, 18, and 19 Stripped Ready for new Steel Jackets and Girders.

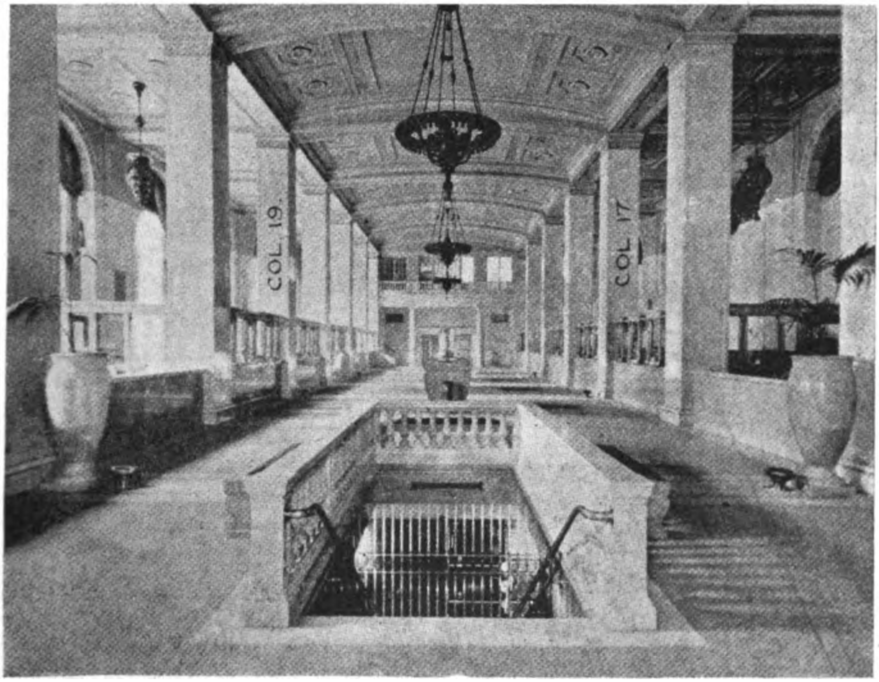
SHORING AND REMOVING HEAVILY-LOADED COLUMNS.

bands of 2 in. by ½ in. steel bars were riveted on the inside of the jacket at intervals of 1 ft. The rivets through the bands were designed to have a resistance to shearing equal in value to the total load on the column. The jackets were punched with $\frac{13}{16}$ in. diameter holes 12 in. on centres horizontally and 6 in. on centres vertically. The purpose of these holes was to ventilate the fluid concrete, thus avoiding air pockets in the concrete fill, to observe the pouring, and to increase the bond resistance. When the concrete was observed at each horizontal row of holes, ¾-in. bolts were pushed through the holes to close them and also to serve as a bond to the jackets between the inside fill and the subsequent fireproofing.

The double girders G2, straddling concrete columns 17 and 19, were cantilevers bearing on temporary columns 17 and 19, and were restrained at girder G1 which was supported on columns 47 and 55. In order to secure the stability of this cantilever, it was necessary to build the addition up to or beyond the ninth floor, dead load alone being considered. Girders G2 were designed for the maximum condition of being supported by the temporary columns 17 and 19 until the permanent columns were in place. These girders were then more than capable of carrying the eccentrically located original concrete columns 17 and 19 and also their proportion of the load from column 18.

The double girders G3, straddling column 18, had their bearing at the ends of the girders G2. The connection of the girders G3 to G2 was made strongest at the inside of girder G2, which would receive the load first. The outside connection was made equal to one-half of the reaction plus the loads from columns 17 or 19. This approximated a condition of fixed ends.

When all of the steelwork was erected and the temporary columns wedged up tight, steel wedges were driven between the ends of the jacket stiffeners and the tops of the girders and diaphragms under the columns 17 and 19. The girders G2 and the temporary columns received their initial stress. The concrete columns 17 and 19 were then cut out one at a



INTERIOR AFTER ALTERATIONS: THE NEW COLUMNS ARE NUMBERS 17 AND 19.

time and replaced by the permanent columns.

The calculated deflection of the girders G3 due to the load transmitted by column 18 was $\frac{3}{16}$ in. The girders were therefore wedged down as far as possible, which, however, only amounted to $\frac{1}{8}$ in., and the wedges were locked. The wedging operation also tended to produce stress in the concrete fill in the jacket and thus afforded a test of the sufficiency of the bond. Column 18 was then cut away beneath the girders G3 and also part way up between the girders, and then six short, heavy-weight 9-in. I-beams, supported on the bottom flanges, were installed under the column. No deflection occurred after the removal of column 18. The space between the column ends and the girders was then filled with concrete and the steel jackets were fireproofed.

Numerous other minor operations were necessary to join the two structures together permanently at other column connections and at each floor level. A definite sequence of operations was planned and adhered to throughout the construction. The fact that the architectural sketches were approved in August, 1922, and the upper stories occupied by tenants in July, 1923, gives evidence of the close adherence to the programme. The structural frame of the addition was actually completed before the columns were cut out and the brick curtain walls of the old rear building line removed.

One difficulty encountered was the concrete spandrel beams which projected above the floor lines in the old rear wall. These projections would have to be cut off to provide uninterrupted floor levels between the old building and the addition. Additional columns 44, 45 and 46 adjacent to old columns 1, 19 and 17 were provided to carry the ends of the beams in the addition. Column 44 started at the first-floor line and terminated at the roof. Columns 45 and 46 started from the diaphragms between girders G2 and also terminated at the roof. Before the projection of the old concrete spandrels was cut off a line of steel beams was installed at each floor between columns 44, 45 and 46; these new steel beams have shelf angles which engaged with the shelf angles on the old beams. The space between the old and new beams was filled solidly with concrete as shown in the detail. In this way the new steel beams carried the new slab and a portion of the load on the old beam, thus, with the removal of the wall load, compensating for the loss of the section.

The Weary and Alford Company, of Chicago, were the architects and engineers, with Mr. Gardner C. Coughlen acting as supervising architect, and Messrs. Kenny Johnson and S. E. Berkenblit as engineers.

IMPURE WATERS FOR MIXING CONCRETE.

SOME exhaustive tests on the effect of using impure water for mixing concrete have been undertaken by Professor Duff Abrams, Professor in Charge of the Structural Materials Research Laboratory at the Lewis Institute, Chicago. The following summary and conclusions are given, by permission, from the paper appearing in full in the copyright Proceedings, 1924, of the American Concrete Institute.

Strength tests of Portland cement concrete were made at ages of 3 days to 2½ years, using mixing waters of a wide range of types many of which were thought to be unsuitable for use in concrete. Sixty-eight samples of water were tested in two different investigations; 52 samples were collected from different sections of the country; 14 were from the Chicago district. Among the waters tested were sea and alkali waters, bog waters, mine and mineral waters, waters containing sewage and industrial wastes, and solutions of common salt. Tests of fresh waters (including distilled) were made for purpose of comparison. About 6,000 tests are included in the report.

SERIES 137 : 50 samples of water were used in 1–4 concrete of relative consistency 1·10, and tested after curing under the following conditions :

(*a*) Moist room tested at ages of 3 days to 2½ years.
(*b*) Moist room 28 days, then in air of laboratory, tested at 3 months to 2½ years.

SERIES 138 : 18 samples, including sewage and trade wastes from the Chicago district, were used in concrete cured in moist room as follows :

(*a*) 1–7, 1–5, 1–4, 1–3 and 1–2 mixtures; relative consistency 1·00, tested at 28 days.
(*b*) 1–4 concrete mix; relative consistency 0·90, 1·00, 1·10, 1·25, and 1·50; tested at 28 days.
(*c*) 1–4 concrete mix; relative consistency 1·00; tested at 3, 7, and 28 days, 3 months, 1 and 2½ years.
(*d*) 1–3 standard sand mortar; tension tests of briquettes and compression tests of 2 by 4-in. cylinders at ages given in (*c*).

Concrete and mortar tests were made in accordance with standard methods. In general, 5 to 10 concrete specimens and 5 mortar specimens were made in a set on different days. Time-of-setting and soundness tests of cement were made with each sample of mixing water.

The principal conclusions from these tests are :

(1) In spite of the wide variation in the origin and type of the waters used, and contrary to accepted opinion, most of the samples gave good results in concrete. This result seems to be due to the fact that the quantity of injurious impurities present is quite small. The following samples gave concrete strengths below the strength-ratio of 85 per cent., which was considered the lower limit for acceptable mixing waters. Acid waters, lime soak from tannery, refuse from paint factory, mineral water from Colorado, and waters containing over 5 per cent. of common salt.

(2) The quality of a mixing water is best measured by the ratio of its 28-day concrete or mortar strength to that of similar mixes with fresh water. While the lowest permissible strength-ratio is a matter of judgment, waters giving strength-ratios which in general fall below 85 per cent. should be considered unsatisfactory; if only isolated tests are made, 80 per cent. should be the limiting value. The time-of-setting test appears to be an unsafe guide as to the suitability of a water for mixing concrete.

(3) Neither odour nor colour is any indication of quality of water for mixing concrete. Waters which were most unpromising in appearance gave good results. It may safely be said, however, that any natural water which is suitable for drinking can be used without question for mixing concrete.

(4) Distilled water gave concrete strengths essentially the same as other fresh waters.

(5) Bog waters, which were thought to be unsuitable for mixing concrete, generally contained only small quantities of foreign materials and gave good results. The strength-ratios for the individual samples were seldom below 90 per cent.

(6) Sulphate waters produced little or no ill effects until an SO_4 concentration of about 1 per cent. was reached. For a concentration of 0·5 per cent. the average reduction in strength was about 4 per

cent.; a concentration of 1 per cent. was required to produce a reduction in strength of more than 10 per cent.

(7) Concrete mixed with sea water (about 3·5 per cent. salts, mostly sodium chloride) cured in the moist room gave higher strengths than fresh-water concrete at ages of 3 and 7 days; at 28 days and over the strength-ratios for sea water ranged from 80 to 88 per cent. Air-cured concrete mixed with sea water was lower in strength than similar fresh-water concrete at 3 months, but showed a recovery in strength at later ages and gave strengths equal to that obtained with fresh water. (In spite of the satisfactory strength results it seems unwise to use sea water in reinforced concrete construction, particularly in the tropics, on account of danger of corrosion of reinforcement.)

(8) Synthetic sea water gave concrete and mortar strengths similar to natural sea water.

(9) Concrete mixed with water containing about 20 per cent. sodium chloride gave strength-ratios from 65 to 77 per cent. at ages of 28 days and over. This water is not satisfactory for mixing concrete unless allowance is made for about 30 per cent. reduction in the assumed strength.

(10) Water containing 0·15 per cent. sodium sulphate and 0·15 per cent. sodium chloride gave normal concrete strengths and showed no ill effects.

(11) Water containing 3·5 per cent. solution of sulphates, largely magnesium; SO_4 concentration 2·8 per cent.; gave strengths similar to that obtained with sea water. The lower strength-ratio was 84 per cent.

(12) Waters from drains and small streams in sulphate districts gave satisfactory strengths at ages up to 2½ years. The lowest strength-ratios were about 90 per cent.

(13) Concrete made with solutions of common salt and cured until test in a moist room showed a slight increase in strength at 3 days for solutions of 10 per cent. and less. Solutions of low concentration (1 and 2 per cent.) also showed a slight increase in strength at 7 days; after 7 days, however, all concentrations gave material reductions in strength. Strength-ratios as low as 60 per cent. were found for a 20 per cent. solution at early ages and for 10 per cent. and 15 per cent. solutions at the later ages. Concrete made with salt solutions and cured in the moist room for 28 days, then in air, gave results at 3 months almost identical with those obtained for moist-room curing. For this curing condition the addition of salt reduced the strength at 1 year about 12 per cent.; at 2½ years there was no reduction in strength. The apparently conflicting results for moist-room and air-curing have not been explained.

(14) The use of common salt for the purpose of lowering the freezing point of the mixing water during cold weather should not be permitted; 5 per cent. of salt lowers the freezing point of water about 6° F., but reduces the strength of concrete about 30 per cent.

(15) Mine and mineral waters gave good results in concrete, with the exception of a carbonated mineral water which gave strength-ratios as low as 80 per cent. Pumpage waters from coal and gypsum mines also gave good results in concrete.

(16) Water containing sanitary sewage gave essentially the same concrete strength as fresh water. Water from the Illinois River, which carries sewage from Chicago, gave strength-ratios at 28 days and 3 months of 83 and 85 per cent. for moist-room curing; for air-curing strength-ratios ranged from 92 to 102 per cent.

(17) Waters containing refuse from oil refineries gave erratic strengths. These samples generally gave strengths near normal, but in some cases material reductions in strength were found. Setting-time of cement with one water sample was: initial 10 hours, final 42 hours.

(18) Water highly polluted with wastes from the Chicago stockyards and giving off an offensive odour showed strength-ratios of about 100 per cent. for all ages, mixes, and consistencies.

(19) Tannery wastes generally gave reductions in concrete strength; the lowest strength-ratios were about 80 per cent. (lime soak water).

(20) Brewery and soap works wastes gave concrete strengths essentially the same as that of fresh water.

(21) Waste from a gas plant and a corn products factory gave good results; the strength-ratios ranged from 90 to 100 per cent.

(22) Paint factory waste water gave

strength-ratios ranging from 80 to 90 per cent.

(23) A spent plating bath containing sulphuric acid, after dilution to 10 and 20 per cent. of its original concentration, gave strength-ratios as low as 85 per cent. for the 10 per cent. solution and 74 per cent. for the 20 per cent. solution. For different consistencies both solutions gave about the same strength-ratios, which ranged from 88 per cent. to 106 per cent. Lower strength-ratios were obtained with the rich concretes than with the lean.

(24) The strength of concrete mixed with all samples of impure waters showed normal increase at 28 days with additional quantities of cement. The impure waters gave about the same strength-ratios regardless of the mix used in the concrete tests. For the usual range in mixtures (1–5 to 1–4) the strength increased about 1 per cent. for each 1 per cent. additional cement.

(25) There was a marked reduction in strength of concrete with increase in quantity of mixing water both for fresh and impure waters. Increasing the quantity of mixing water 1 per cent. reduced the strength of concrete about the same amount as if the quantity of cement were reduced 1 per cent. A comparatively slight increase in quantity of mixing water produced a greater reduction in concrete strength than that caused by the use of the most polluted mixing water that is ordinarily encountered. These tests show the importance of the water-ratio strength relation in concrete which has been pointed out in numerous other reports from this Laboratory.

(26) The effect of impure water was in general independent of the consistency of the concrete. Acid waters from a spent plating bath gave somewhat higher strength-ratios in the wetter concretes.

(27) The strength of concrete cured in a damp condition at normal temperatures increased with age for both fresh and impure waters. The strength was approximately proportional to the logarithm of the age at test.

(28) The effect of impure mixing waters on the tensile and compressive strength of 1–3 standard sand mortar at ages of 3 days to 2½ years was generally similar to that on the compressive strength of concrete. In the mortar tests a few waters gave somewhat higher strength-ratios, and one water gave a somewhat lower strength-ratio than was obtained in concrete.

(29) The percentage of water required for normal consistency of cement when mixed with the impure waters was, with few exceptions, about the same as for fresh waters. Water containing solutions of 5 to 20 per cent. of common salt, refuse from an oil refinery, water containing sulphates, par. (11), and acid water from a spent plating bath, required somewhat higher percentages for normal consistency than fresh water.

(30) The time-of-setting of Portland cement mixed with the impure waters was about the same as for fresh waters. There were, however, some notable exceptions. In most instances the samples giving low concrete strength-ratios were slow setting. On the whole the tests show that time of setting is not a satisfactory test for suitability of a water for mixing concrete.

(31) None of the impure waters caused unsoundness of the Portland cement when subjected to the standard test over boiling water.

(32) Most specifications for water for mixing concrete are so worded that they would, if strictly enforced, exclude nearly all but rain water and distilled water; these tests have shown that almost any impurity may be present without necessarily producing ill effects. The important point is not whether impurities are present, but do the impurities occur in injurious quantities ?

(33) The effect of sugar and similar compounds was not studied; earlier tests have shown that these compounds are most detrimental and must be avoided.

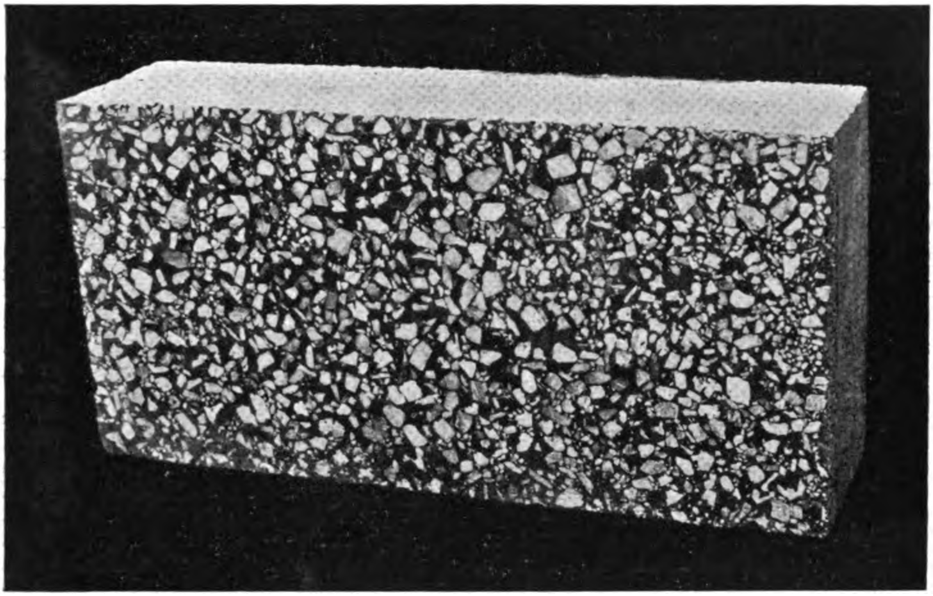
CONCRETE PRODUCTS.

COLOURED CEMENT.

THE view is becoming more generally adopted that from the point of view of the architect and from the artistic standpoint generally, concrete should be regarded as an artificial stone and not an imitation stone. As a cast stone, concrete may be considered as a conglomerate of small stone (including sand) bound together with cement which is prepared by the burning and suitable treatment of other mineral substances. This seems from every standpoint a legitimate expedient for the use of small stone as a constructional material, and the use of concrete in this sense should not offend reasonable taste. It is, indeed, where steps are taken to reveal the true nature of concrete by scrubbing the surface and exposing the aggregate embedded in a matrix of cement that the most pleasing effects are obtained. On the other hand, attempts to make concrete appear to be a solid homogeneous stone indistinguishable from natural stone, except on minute examination, are open to criticism on the ground that a sham is produced. Truly this insistence on the " real thing " may be an expensive taste, and the man of small means desiring stonework for his residence or garden will be sorely tempted to abandon such an ideal on seeing the excellent imitation of stone shown at the Concrete Utilities Bureau exhibit at Wembley in the construction of a screen and office building.

Upon first consideration it might seem that the use of coloured cement would be banned by the æsthetic mind, but it has to be remembered that ordinary cement ranges in colour from white to dark grey according to the proportion of iron it contains, and there is nothing derogatory in adding other mineral compounds to bestow any other colour or tint. The artistic treatment of concrete is indeed developing by the use of coloured cements. The addition of colouring matters to concrete is of long standing, although largely confined to the use of oxide of iron to produce a red colour. It is, however, a matter of great difficulty to obtain an even distribution of a coloured powder with the other ingredients of concrete under the ordinary conditions of concrete mixing, and in the result a coloured surface of irregular shade is frequently obtained. This factor has doubtless hindered the development of coloured concrete, and hence the production of coloured cement in which the cement and colouring matter are evenly mixed in the correct proportions to produce a desired shade is a step in the right direction and one that should popularise the use of colour in concrete. It is in fact now possible to obtain coloured cements in more than twenty different tints which can be chosen in the same way that decorative paint shades are chosen.

The introduction of colouring matter into cement requires to be done with discrimination, because owing to the alkaline nature of cement there are possibilities of chemical reaction occurring with certain materials which would cause the colouring to be evanescent and might lead to other undesirable results. The colouring materials must therefore be inert when in contact with cement, and stable to the action of light and moisture. Generally speaking, metallic oxides are the safe materials to employ. Moreover, the colouring matters are in the form of finely-divided powders and the addition of fine powders to cement almost inevitably reduces the strength of the latter. Hence only a good cement should



BUILDING BLOCK FACED WITH BLACK CEMENT AND WHITE MARBLE AND FINISHED WITH A MARBLE POLISHING MACHINE.

be used as a base for colouring, while the proportion of colour added should not be excessive.

With light tints a high proportion of colouring matter would be needed to predominate over the grey colour of cement, and in many cases white Portland cement is used as the basis to avoid excessive proportions of added colour.

It is indeed necessary from several standpoints that the production of coloured concrete should not be done in a haphazard manner but under scientific supervision, and for this purpose it is desirable that the production of coloured cements should be undertaken by the cement manufacturer, who is best equipped with knowledge as to the colouring materials that can be safely added to cement and who also has the facilities for regular and intimate mixing.

As already indicated, the commonest colour employed in concrete is red produced by red oxide of iron, the latter being one of the cheapest colouring matters available. Red concrete tiles are probably the most prominent example of this, and red cement mortar may be used for pointing these or ordinary terra-cotta tiles while black cement mortar is used for pointing dark blue ridge tiles. One of the most modern examples of coloured cement is for concrete tennis courts which are surfaced with green concrete, thus producing a surface which is not dazzling to the eyes of the players, as an ordinary concrete tends to be in bright sunlight.

When it is remembered that the colours available are red, yellow, brown, and green, with numerous shades, and that white and black cements are also obtainable, it will be realised that the decorative possibilities of coloured cements for floors, panels, rough-casting, etc., cover a wide range. In conjunction with coloured aggregates it is possible to see unlimited scope for the artistic designer.

APPLICATIONS OF COLOURED CEMENT.

On the previous page this month we refer to the possibilities of a more extended use of concrete products if advantage be taken of the effects which may be obtained by the incorporation of coloured cements. Messrs. G. and T. Earle, Ltd., of Hull, are now manufacturing cements in a variety of colours and shades, which have been used for the following purposes, among others:

Boston Spa Church.—Used on chimney stack, to match the old stone work. (Yellow cement.)

Liverpool.—A light-cream coloured cement was used for stucco work on one of a series of detached villas at Grassendale, doing away with the garishness common to newly-erected houses, and giving a mellow appearance.

Runcorn.—A public convenience erected at one end of a bridge on a main thoroughfare was rendered with stone-colour cement and afterwards lined out, the whole blending with the stonework of the bridge, which was built of Runcorn stone.

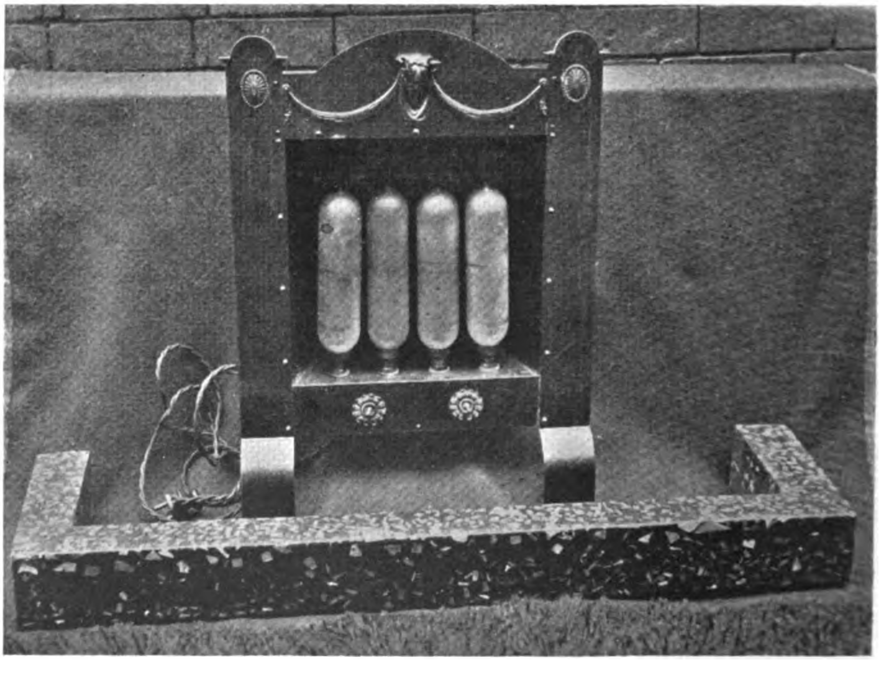
Middlesbrough. — Stone - colour cement used in the North Ormesby Cottage Hospital to match stone work.

Bradford.—Used to match half-timbered work for the gable ends of houses. The mixture used was 3 of sand to 1 of cement (burnt umber colour), put on in 2 coats about ¾-in. thick. This kind of work does not, of course, rot like timber.

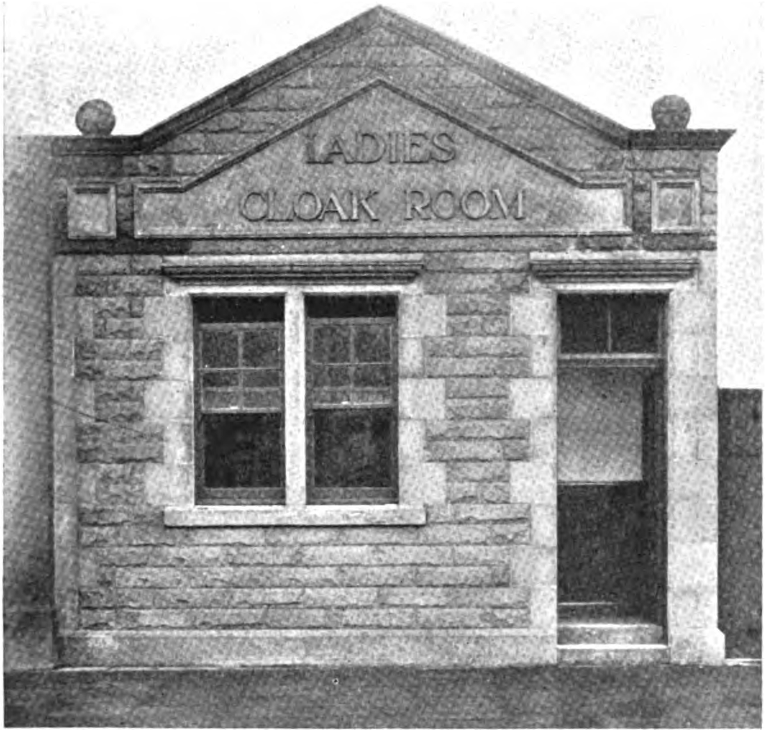
Boston Spa.—Black cement used to point dark blue ridge tiles on houses.

Crewe.—Black cement used to make a black floor, surfaced with spar chippings, which was afterwards washed with spirits of salt, then rubbed with sandstone, and later polished with ordinary floor polish.

Sheffield. — Building blocks with black cement face and white marble, polished by a marble finishing machine (see illustration, p. 531.)



Concrete Kerb faced with Black Marble and Mother-of-Pearl.



This Structure, built of Concrete Blocks, was erected by Mr. David Macnair, of Falkirk.

Sheffield.—Kerb faced with black marble and mother of pearl (see illustration, opposite.)

Boston Spa.—Terra-cotta colour cement used to point terra-cotta ridge tiles.

Bradford.—Garage floor, in proportions of 3 of limestone, 2 of sand, and 2 of terra-cotta colour cement, the topping of coloured cement being put down ¾-in. thick.

Rawdon.—Used in the flight of steps leading to the Temperance Hall. The steps were made with a core of ordinary cement, and faced with terra-cotta cement ½-in. thick, in the proportion of 1 : 3 Horsforth sand.

Boston Spa.—Red cement used for kitchen floors, porches, and similar small work.

Glossop.—Red cement used in the floor of the lych gate war memorial.

Salford.—Concrete steps with a facing of red cement.

Sowerby Bridge.—Concrete ventilators made with brick-red cement.

Malton.—Floor of a porch, laid with brick-red cement which can be polished.

Other uses to which coloured cements have been put include: Dados in corridors; inn signs and lettering; bathroom floors; window sills; garden paths; fireplaces; café entrances; porch panels; decorative garden flower vases on pedestals; filling in cavities of decayed brick walls; and rough casting. The building block and kerb illustrated this month were made by Mr. A. Gilman, of Sheffield.

SOLID CONCRETE WALLS.

THE "Bendall" walling system, illustrated herewith, has been specially designed so that the use of shuttering is avoided so far as the external walls are concerned. The section in *Fig.* 1 shows a 9-in. wall the inner face of which is constructed of clinker slabs. These form the permanent inner face of the wall, and their use prevents condensation. The slabs are usually 18 in. long, 19 in. wide, and 2½ in. thick, but these dimensions are not essential and larger or smaller units can be used.

The exterior face of the wall consists of concrete tiles of any colour, and the ties and slabs are locked tightly together with hard, cold-drawn, steel wire ties. The method of fastening is shown in *Fig.* 2. The space between the inner slabs and the tiles is filled with concrete which is tamped in the usual way, and the resultant wall is impervious to damp and free from the troubles of condensation.

It is claimed that with this system two men without experience of similar construction can erect 25 super yds. of 8½-in. wall in five hours without undue effort. In a test it was found that an experienced man could prepare a super yard of 9-in. wall, fixed ready for the concrete to be poured in, in eight minutes.

The method of erection of this system is as follows :—After the foundations are in position and the dampcourse laid (if this is required by local authorities), the first row of slabs forming the interior face of the wall is erected with cement mortar

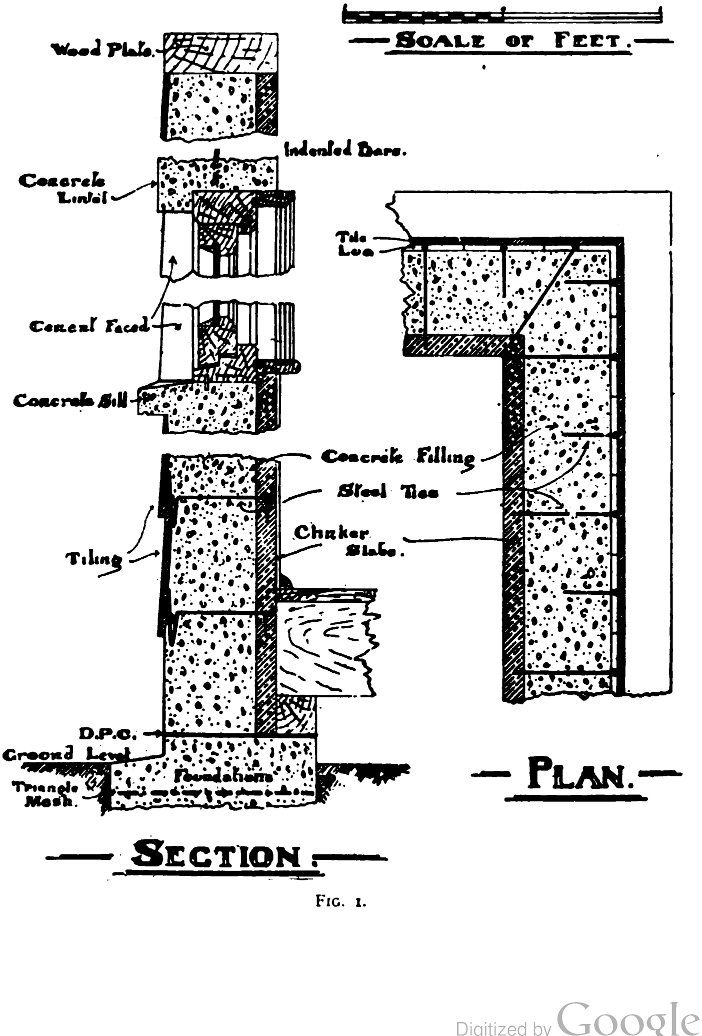


FIG. 1.

joints. The bottom row of tiles on the outer face is then placed in position so that the top of the tile lug is on a level with the lower side of the clinker slab. In order to prevent any movement of this first row, the steel ties are inverted through the holes of the tile lug and secured into the foundation. Sufficient concrete is then poured in to fill up the cavity thus formed to two-thirds the height of the tile. As soon as this concrete is set the building of the wall may proceed as rapidly as the labour provided will permit.

The steel ties are **V**-shaped; the two ends forming the top of the **V** are inserted in each tile of the second row, and the projecting ends enter through the lug locking the tiles of the first row with those of the second. The bottom of the **V** extends to the clinker slab, to which it is secured by driving a large-headed nail through the eye of the tie so that when the concrete has been poured in position the tile is firmly bedded in the concrete.

Tiles composed of concrete of various colours are used for the wall face, the size of the units being usually 10½ in. long by 6½ in. wide and ½ in. thick, the lap of the tiles being 1 in.; in order to facilitate locking the tiles together the top of each tile is tapered. Excellent colour effects can be obtained with concrete tiles, and they have the further advantage that they can be made on the site of the building, thus saving the cost of carriage and risk of breakage during transit. The height to which the slabs and tiles may be erected before concrete is poured is from 2 to 3 ft.

It is claimed by the inventor and patentee (Mr. R. L. Bendall, of 40 Richmond Wood Road, Bournemouth) that this walling system compares very favourably with alternative methods. In the case of a 9-in. wall, the materials are 2 in. of clinker slab, 6½ in. of concrete, and ½ in. of tile; this, we are informed, represents a saving of approximately 3*s*. per super yard in favour of the tile wall in material alone, while the rapidity with which this type of wall can be constructed is a factor of considerable advantage.

Fig. 3 shows a building recently erected for the Corporation of Christchurch,

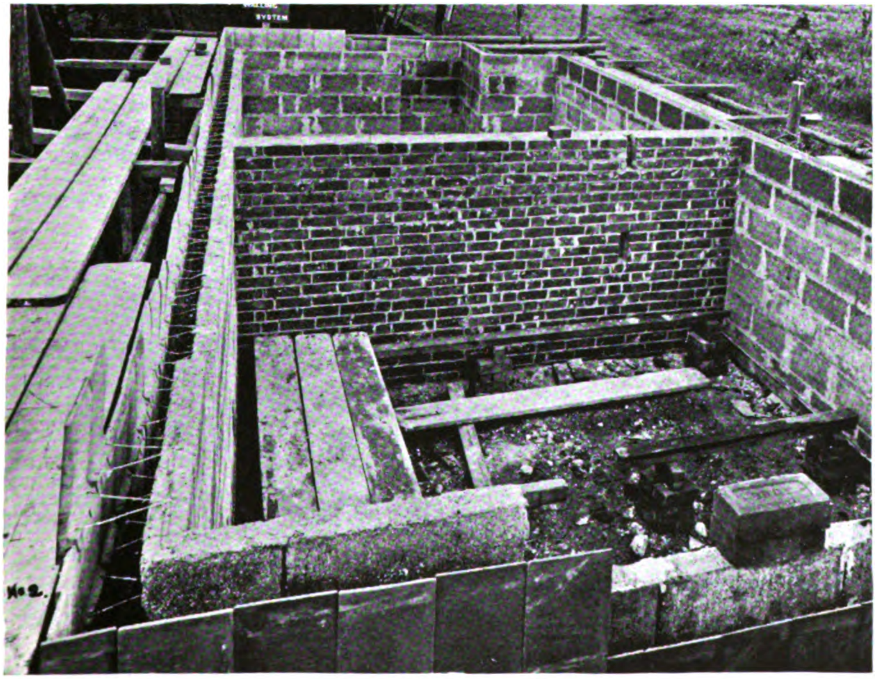


FIG. 2.

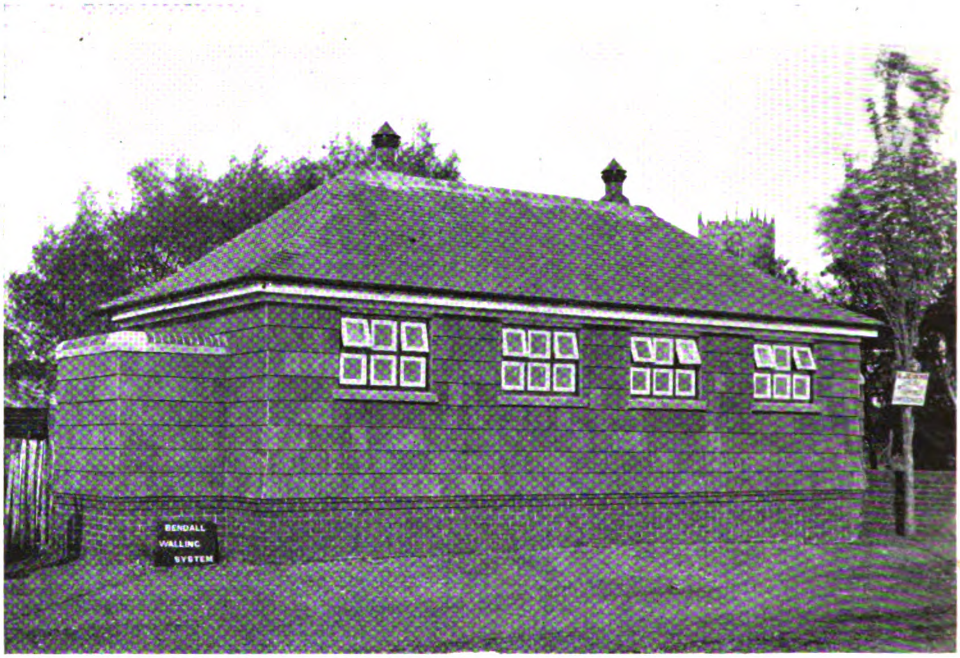


Fig. 3.

Hampshire, to the design of the Borough Engineer and Surveyor, Mr. H. J. Farmer. This building is exposed to gales from all points, while on the south side the land is open to the sea, but we are informed there is not the slightest sign of dampness in the interior of the structure. The tiles are made of concrete of a nut-brown colour. The woodwork is painted a middle green, with white casements. Although there were many openings in the walls of this building, no difficulty was found in housing the tiles around the window sills; and where the downpipes pass and overflow pipes pierce the walls it was found a simple matter to drill the necessary holes in the tiles and plug and drive nails into the concrete in the usual manner. A range of 21 shades can be produced in the concrete tiles.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	„	14	0
„ „ ½ in. mesh	„	15	0
Best British Portland Cement	per ton 58s. to	63	0
"Ferrocrete" Portland Cement	10s. per ton extra		

Boarding for Shuttering—		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	„	29	6	33	6
1½ in.	„	35	6	41	0

Sawn Timber for Struts and Supports—	
3 in. by 4 in.	from £24 10s. per standard
3 in. by 6 in. and 3 in. by 7 in.	„ £25 10s. „ „

Mild Steel Rods for Reinforcement—		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
5/16 in. to ½ in. Rounds	„	13	6
⅜ in. Rounds	„	14	6
¼ in. Rounds	„	15	6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed with Clean Water in proportion 1 : 2 : 4—		s.	d.
Do. do. in foundation	per yard cube	45	6
Do. do. in columns	„ „	50	6
Do. do. in beams	„ „	50	6
Do. do. in floor slabs 4 in. thick	per yard super	5	4
Do. do. in floor slabs 6 in. thick	„ „	7	11
Do. do. in floor slabs 9 in. thick	„ „	11	6
Do. do. in walls 6 in. thick	„ „	8	2

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—		s.	d.
From ¼ in. to ⅜ in.	per cwt.	24	0
„ 5/16 in. to ½ in.	„	23	0
„ ⅝ in. to 2⅞ in.	„	22	0

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.*

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.*

Shuttering—		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	55	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	51	0
Do. do. in small quantities	per ft. super	0	9½
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last, in narrow widths	„ „	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	„ „	1	1
Do. do. as last, in narrow widths	„ „	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	„ „	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are those current in the London area, namely:—Carpenters and joiners, 1/8 per hour; Labourers on building works, 1/3; Operators on concrete mixers and hoists, 1/4.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

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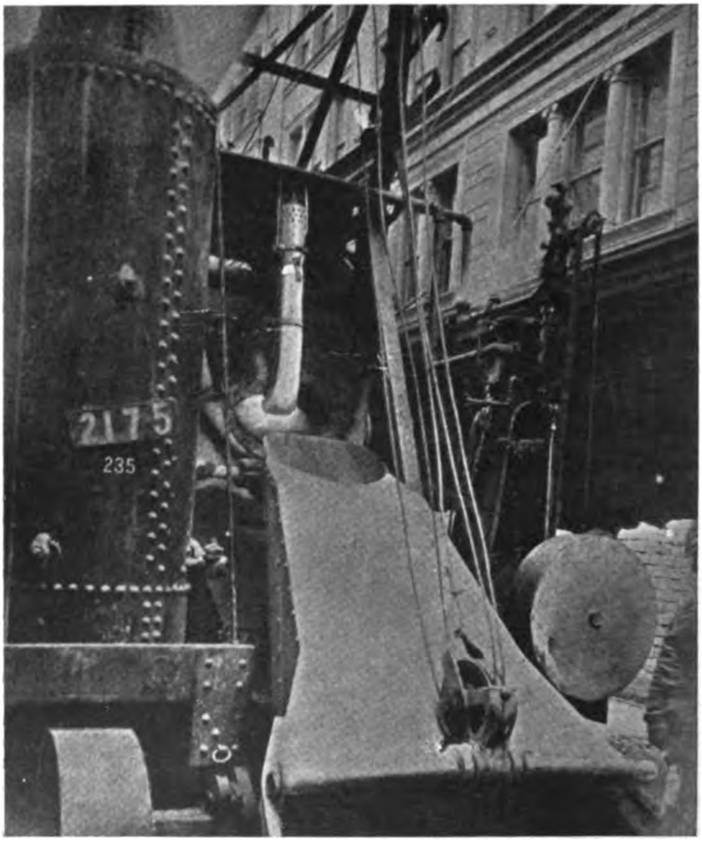

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TYDD ST. GILES.—*Bridge.*—The Isle of Ely and Holland County Councils have accepted the tender of the Yorkshire Hennebique Contracting Co., at £2,508, for the construction of a ferro-concrete bridge over the Old Shire Drain.

UXBRIDGE. — *Reservoir.* — The U.D.C. has accepted the tender of the Indented Bar & Concrete Engineering Co., Ltd., at £4,879 7*s.* 6*d.*, for the construction of a reinforced concrete reservoir.

WOLVERHAMPTON. —*Concrete Houses.* —The T.C. has accepted the tender of Mr. M. A. Boswell, Wolverhampton, for the construction of 56 concrete houses.

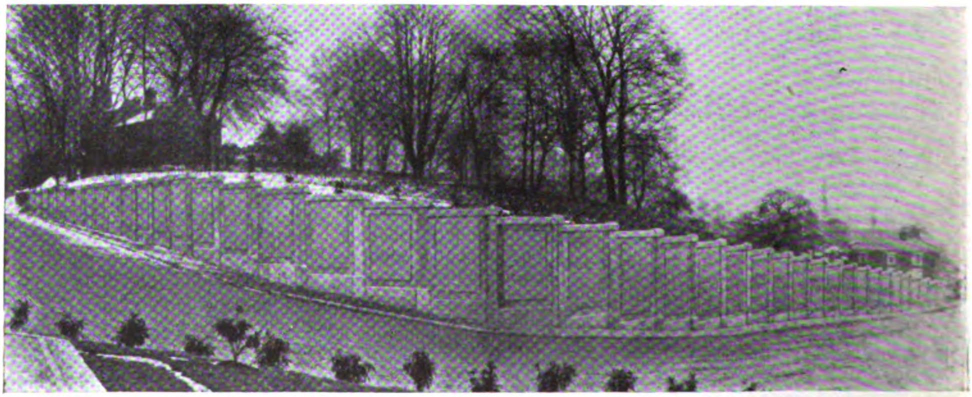
REINFORCED CONCRETE RETAINING WALL.

THE reinforced concrete retaining wall illustrated below was recently completed at Rood Hill, on the main road between Congleton and Manchester, which is considered the main link between the Potteries and the industrial centre of Lancashire and is extensively used by mechanical transport. Originally there was a very sharp bend and heavy gradient at Rood Hill.

The scheme, which was prepared by Mr. P. A. Watford, M.Inst.M. and Cy.E., late Borough Surveyor of Congleton, provided for the widening of the roadway for a length of approximately 450 ft., increasing its width up to 75 ft. at the centre of the bend, and for the construction of a retaining wall, etc. The work was executed on the Hennebique system by the Yorkshire Hennebique Contracting Co., Ltd., with cement supplied by Messrs. G. & I. W. Carter, Ltd., of Lawton Street, Congleton, to designs prepared by Messrs. L. G. Mouchel & Partners, Ltd., of Westminster.

The wall varies in height from 12 ft. to 20 ft., and is founded on an extended footing varying from 5 ft. to 9 ft. in width, constituting a continuous slab stiffened by longitudinal beams on the underside. Counterforts are placed from 10 to 12 ft. apart at the back of the wall. At suitable intervals special expansion joints have been provided.

The completion of the scheme was commemorated in February, 1924, when the works were officially opened by Sir Henry Maybury, K.C.B., representing the Ministry of Transport, in the presence of the Mayor and Corporation and a large gathering of interested spectators. Another part of the scheme, the road lighthouse, the latest "safety first" idea in ferro-concrete, was illustrated in our last issue.



REINFORCED CONCRETE RETAINING WALL.

NEW ADJUSTABLE INSERT FOR MACHINE MOUNTING.

For the purpose of fastening machinery or other equipment to concrete floors, walls, or ceilings a new adjustable bolt insert has been designed by the Westinghouse Electric and Manufacturing Company. The Westinghouse insert permits an adjustment of the bolt position after the concrete has set, and is claimed to result in more satisfactory machine mounting. The adjustable insert consists of a cast-iron housing with a tapering body and containing a rotatable bolt carrier. The bolt carrier is T-slotted to take the head of a standard machine bolt, and is of sufficient length to permit a ⅜-in. movement of the bolt from the centre. Since the carrier can be rotated, the adjustment of the position of the bolt can be secured in any direction. The housing and bolt carrier are provided with teeth which mesh and prevent any change in position after the adjustment has been made and before the bolt has been tightened. The teeth are kept in mesh by a retaining spring which is held in by a sheet metal plate at the back of the housing.

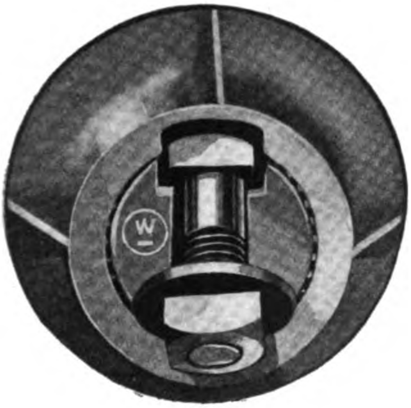


Fig. 1.

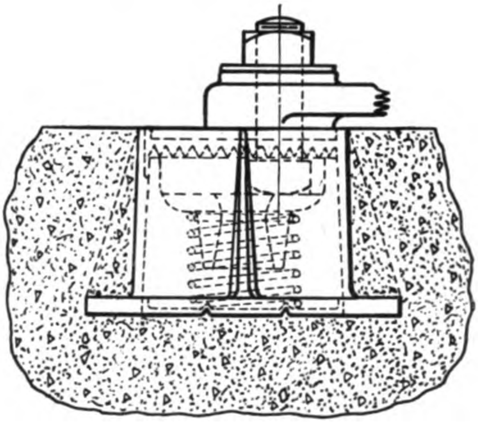


Fig. 2.

When the insert is to be installed, the form for the concrete is drilled at the point desired for the bolt. The insert is then fastened tightly to the form by a bolt run through the form and screwed into a nut placed in the T-slot of the bolt carrier. After the concrete has set for a suitable length of time this bolt and nut are removed and a bolt of the proper length is placed in the bolt carrier, which is rotated until the bolt is in the correct position to receive the base of the apparatus to be mounted. The nut is then tightened on the bolt and the position is fixed.

These inserts, which are available for ⅜-in. or ½-in. machine bolts, are stated to have great holding power when embedded in concrete, due to the fins and flange which are cast as an integral part of the housing. We are informed that the holding power of the combination equals the ultimate strength of the bolt.

Fig. 1 shows how the bolt is placed in the slot. *Fig.* 2 shows the insert embedded in concrete with the bolt in adjusted position and tightened over machine base or foot.

NEW CONCRETE ROAD AT BRISTOL.

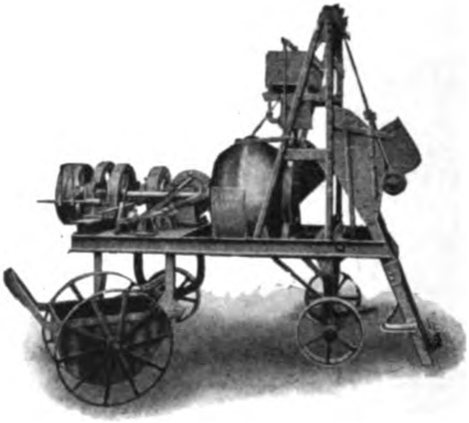
The members of the Sanitary Committee of the Bristol Corporation recently paid a visit of inspection to the Low Level Road, Bristol. Mr. Lessel S. McKenzie, the City Engineer, and the Assistant Engineer, Mr. G. Ford, accompanied the Committee. The City Engineer explained the details of the road, which has a length of about five miles, the width varying from 100 to 65 ft. The wider portion has a concrete surface, and is reinforced with B.R.C. Fabric. It is intended that these sections will carry railless 'bus traffic, as well as other traffic.

CENTRIFUGAL CONCRETE MIXERS.

MESSRS. Builders and Contractors Plant, Ltd., write :

" We read the article in your June issue about a new centrifugal concrete mixer with interest, as we have been for many years manufacturers of the " Roll " concrete mixer, which acts entirely on the centrifugal principle of mixing, with complete success. The illustration shows one of our 3 cu. ft. size portable mixers, with power unit, with the drums closed for mixing. These drums revolve on a central shaft, the mixing being effected by the centrifugal action set up within them, by which the concrete is thrown upwards and towards the sides of the drum and returns by gravity to the centre and lower portion. In this way a large batch is handled in a small diameter drum. A feature of the " Roll " is the quick discharge ; the drums are divided down the centre, and by simply throwing over a lever one half of the drum opens a sufficient width for the entire batch to be discharged practically instantaneously. The interior of the drum is not equipped with multiple mixing blades, so that the effort required in the form of power to drive it is very low.

" The drum actually revolves at a speed of about 20 r.p.m. which is quite sufficient for setting up the requisite centrifugal force, and at the same time the wear on the working parts is very much less than if the drums were revolved at a higher speed. At the Cardiff Conference of the Institution of Municipal and County Engineers trials reported that this mixer ' is an excellently designed machine, soundly constructed and of ample strength. It is very compact. The mixing of all the three grades of mixtures put through the machine was carried out in a thoroughly efficient manner.' "



RECENT PATENT APPLICATIONS.

214,779. Babcock & Wilcox, Ltd. (Babcock & Wilcox Co.). Cement-kiln systems.

214,902.—W. S. Peggs. Reinforcement for concrete.

215,103.—J. H. Peters. Concrete mixing and spreading machines.

215,538. — A. Drummond : Rotary cement-grinding and like apparatus.

215,681.—H. W. Snelling : Means for holding fencing wire to concrete posts.

216,016.—T. Nose : Process of constructing culverts or pipes of concrete.

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ISSUED MONTHLY

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By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

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MANUFACTURED BY

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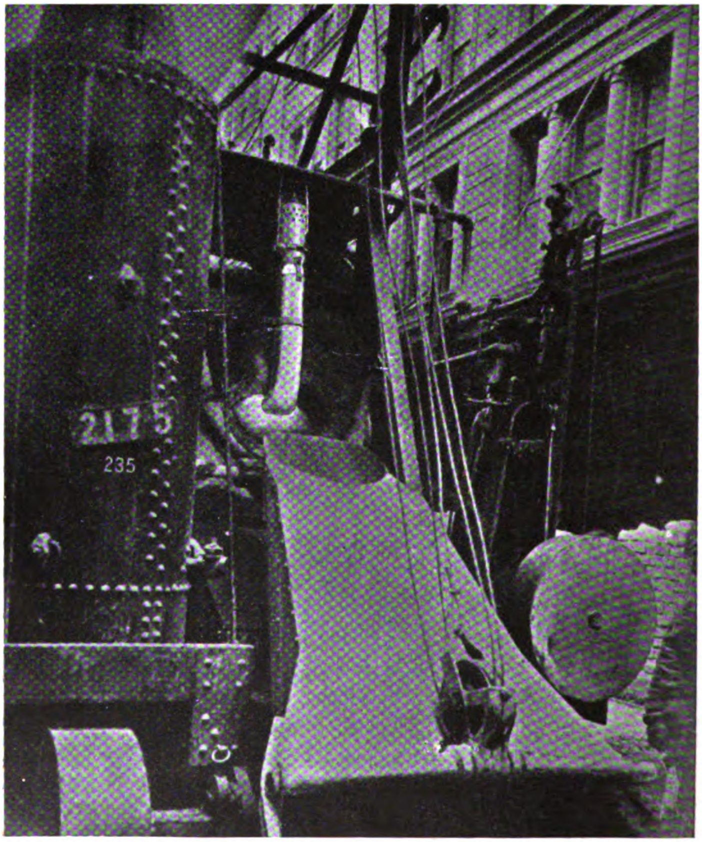

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SMETHWICK. — *Bridge.* — The T.C. has accepted the tender of Messrs. Gray's Ferro Concrete Co., Glasgow, at £5,367, for the construction of a reinforced concrete bridge.

SOUTHEND-ON-SEA. — *Concrete Pipes.* —The T.C. has accepted the tender of Messrs. J. Ellis & Sons, for the supply of large concrete pipes for sewers in Fairfax Drive Valley.

TYDD ST. GILES.—*Bridge.*—The Isle of Ely and Holland County Councils have accepted the tender of the Yorkshire Hennebique Contracting Co., at £2,508, for the construction of a ferro-concrete bridge over the Old Shire Drain.

UXBRIDGE. — *Reservoir.* — The U.D.C. has accepted the tender of the Indented Bar & Concrete Engineering Co., Ltd., at £4,879 7*s*. 6*d*., for the construction of a reinforced concrete reservoir.

WOLVERHAMPTON. —*Concrete Houses.* —The T.C. has accepted the tender of Mr. M. A. Boswell, Wolverhampton, for the construction of 56 concrete houses.

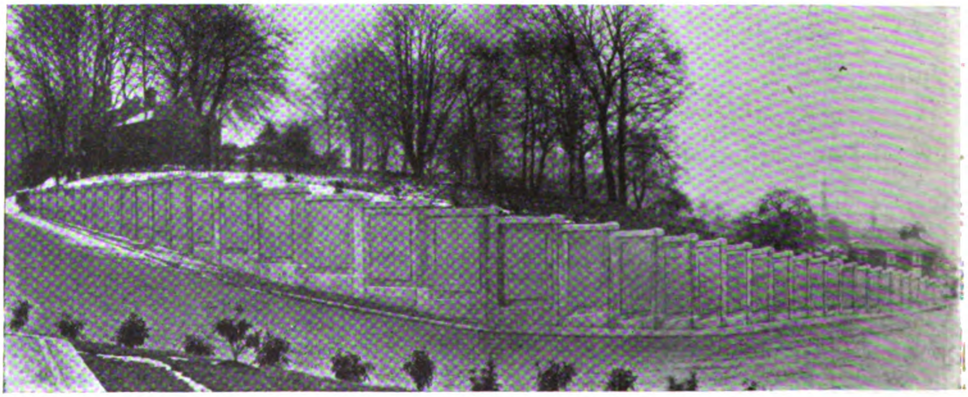
REINFORCED CONCRETE RETAINING WALL.

THE reinforced concrete retaining wall illustrated below was recently completed at Rood Hill, on the main road between Congleton and Manchester, which is considered the main link between the Potteries and the industrial centre of Lancashire and is extensively used by mechanical transport. Originally there was a very sharp bend and heavy gradient at Rood Hill.

The scheme, which was prepared by Mr. P. A. Watford, M.Inst.M. and Cy.E., late Borough Surveyor of Congleton, provided for the widening of the roadway for a length of approximately 450 ft., increasing its width up to 75 ft. at the centre of the bend, and for the construction of a retaining wall, etc. The work was executed on the Hennebique system by the Yorkshire Hennebique Contracting Co., Ltd., with cement supplied by Messrs. G. & I. W. Carter, Ltd., of Lawton Street, Congleton, to designs prepared by Messrs. L. G. Mouchel & Partners, Ltd., of Westminster.

The wall varies in height from 12 ft. to 20 ft., and is founded on an extended footing varying from 5 ft. to 9 ft. in width, constituting a continuous slab stiffened by longitudinal beams on the underside. Counterforts are placed from 10 to 12 ft. apart at the back of the wall. At suitable intervals special expansion joints have been provided.

The completion of the scheme was commemorated in February, 1924, when the works were officially opened by Sir Henry Maybury, K.C.B., representing the Ministry of Transport, in the presence of the Mayor and Corporation and a large gathering of interested spectators. Another part of the scheme, the road lighthouse, the latest "safety first" idea in ferro-concrete, was illustrated in our last issue.



REINFORCED CONCRETE RETAINING WALL.

NEW ADJUSTABLE INSERT FOR MACHINE MOUNTING.

For the purpose of fastening machinery or other equipment to concrete floors, walls, or ceilings a new adjustable bolt insert has been designed by the Westinghouse Electric and Manufacturing Company. The Westinghouse insert permits an adjustment of the bolt position after the concrete has set, and is claimed to result in more satisfactory machine mounting. The adjustable insert consists of a cast-iron housing with a tapering body and containing a rotatable bolt carrier. The bolt carrier is T-slotted to take the head of a standard machine bolt, and is of sufficient length to permit a ⅝-in. movement of the bolt from the centre. Since the carrier can be rotated, the adjustment of the position of the bolt can be secured in any direction. The housing and bolt carrier are provided with teeth which mesh and prevent any change in position after the adjustment has been made and before the bolt has been tightened. The teeth are kept in mesh by a retaining spring which is held in by a sheet metal plate at the back of the housing.

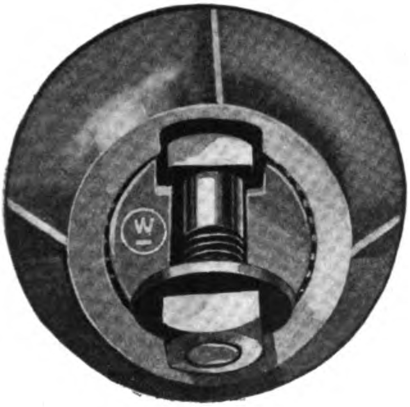


Fig. 1.

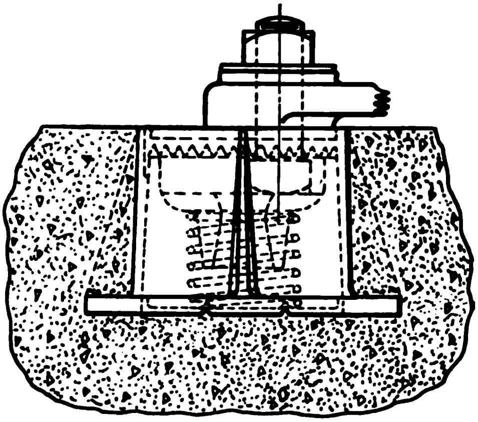


Fig. 2.

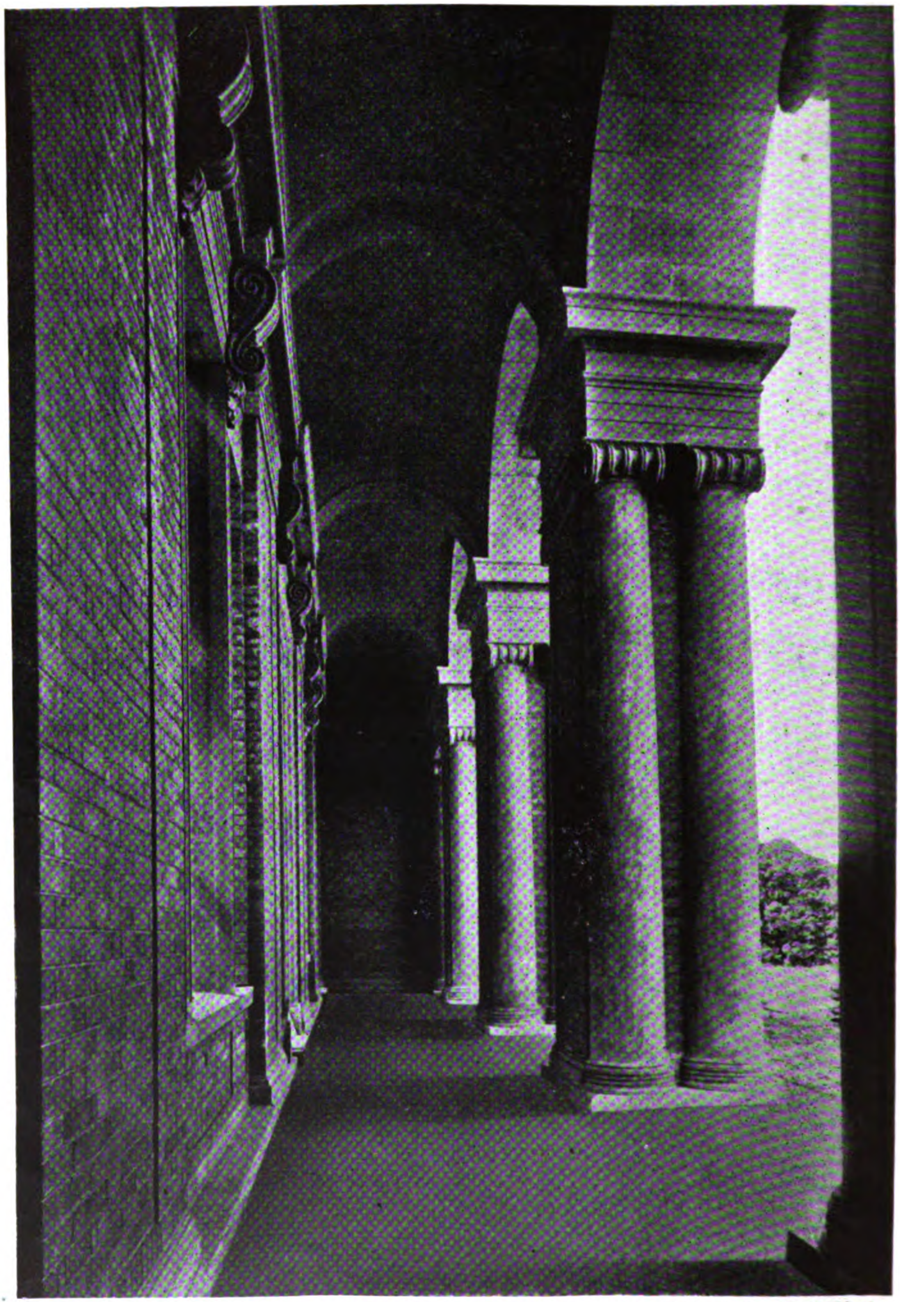
When the insert is to be installed, the form for the concrete is drilled at the point desired for the bolt. The insert is then fastened tightly to the form by a bolt run through the form and screwed into a nut placed in the T-slot of the bolt carrier. After the concrete has set for a suitable length of time this bolt and nut are removed and a bolt of the proper length is placed in the bolt carrier, which is rotated until the bolt is in the correct position to receive the base of the apparatus to be mounted. The nut is then tightened on the bolt and the position is fixed.

These inserts, which are available for ⅜-in. or ½-in. machine bolts, are stated to have great holding power when embedded in concrete, due to the fins and flange which are cast as an integral part of the housing. We are informed that the holding power of the combination equals the ultimate strength of the bolt.

Fig. 1 shows how the bolt is placed in the slot. *Fig.* 2 shows the insert embedded in concrete with the bolt in adjusted position and tightened over machine base or foot.

NEW CONCRETE ROAD AT BRISTOL.

The members of the Sanitary Committee of the Bristol Corporation recently paid a visit of inspection to the Low Level Road, Bristol. Mr. Lessel S. McKenzie, the City Engineer, and the Assistant Engineer, Mr. G. Ford, accompanied the Committee. The City Engineer explained the details of the road, which has a length of about five miles, the width varying from 100 to 65 ft. The wider portion has a concrete surface, and is reinforced with B.R.C. Fabric. It is intended that these sections will carry railless 'bus traffic, as well as other traffic.



[*Mr. T. H. F. Burditt, Architect.*

CONCRETE FACTORY BUILDING AT BALDOCK: COLONNADE AT MAIN ENTRANCE. (*See* p. 557.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIX. No. 9. LONDON, SEPTEMBER, 1924.

EDITORIAL NOTES.

THE CONDUCT OF INDUSTRIAL DISPUTES.

AFTER a strike and lockout of seven weeks' duration, the dispute in the building industry has been settled by a compromise, as all differences between reasonable men are adjusted. But when the agreement reached varies the existing conditions hardly at all, those other large interests directly concerned in building, and the general public, might fairly be entitled to ask whether such a serious dislocation is necessary to achieve so little. An increase of a halfpenny an hour in wages was offered by the employers before the strike took place, and refused —it has now been accepted; one of the chief aims of the employers was stated to be the inclusion of Liverpool in the national agreement—they have now agreed that Liverpool is to work on its local agreement for a further fifteen months; payment, or part payment, for time lost through inclement weather was an essential part of the operatives' demands—it has now been shelved for a committee to "endeavour" to report on in six months' time; another essential laid down by the leaders of the operatives was a forty-four-hour week all the year round—but it has been agreed that except where other local arrangements are entered into the recognised hours of labour shall be 46½ in the summer months. With all due allowance for the time taken up in jockeying for position, or, as one of the operatives' leaders put it, "changing their policy to meet the tactics of their opponents," surely it was not necessary to hold up the second largest industry in the country for seven weeks to agree amicably to such slight alterations to the existing order of things?

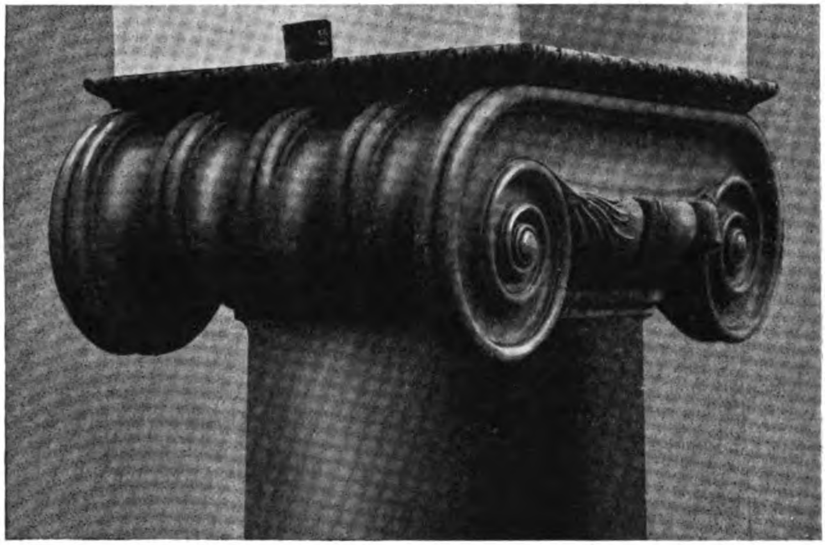
On the face of it the employers have got the better of this long argument, if there can be gain to any party engaged in industrial strife in which employers and employed whose interests are so essentially bound up that the one is impotent without the other refer to each other as their "opponents." But are there not other, and perhaps more important, interests vitally concerned in the dispute; are there not people with even more to lose by a stoppage of building work than the employers and operatives immediately concerned? There are four parties to any building contract, the client, the architect or engineer, the builder, and the operatives, and the manufacturers of materials are also concerned. Is there not something wrong with the system by which in such a dispute negotiations are carried on, at what to the man in the street seems inordinate length, behind closed doors, by two of these parties only? Whatever the upshot, whether a halfpenny or twopence be added to wages, the public, represented by that section engaged in building enterprises, has to pay it, and yet they have no voice in the matter. The architect and engineer, who know more than anyone else the amount of building work held up on account of high costs, are not invited or permitted to bring their knowledge to the council chamber. In the opinion of many such a dispute would have been settled much sooner if representatives of the public, who are after all the deciding factors in the cost of building, had been asked to join in the discussions. But the architect and engineer, who are affected quite as much as the builder or workman, and who, we are sure, would be very willing to help the other parties to arrive at a speedy decision, are ignored; while the building owner, who is losing heavily owing to the delay in completion of work in which his money is invested, has a feeling that he certainly ought to have some say in deliberations which result in his building costing more than he bargained for when he started on the enterprise. The recent tramways dispute, in which owners and workers and independent witnesses were called to give evidence in open court, has much to commend it, and might well be extended to all industrial disputes.

LONDON COUNTY COUNCIL REGULATIONS.

THE announcement that Mr. G. Topham Forrest, Superintending Architect of the London County Council, is to visit the United States this month to obtain the most up-to-date information on modern methods of building, particularly in regard to steel-frame and reinforced concrete construction, and report thereon to the Building Acts Committee, will be welcomed by all concerned with reinforced concrete construction in this country. There is no doubt that the L.C.C. Regulations for Reinforced Concrete Construction are now considerably out of date, and their stringency is a considerable factor in retarding the development of reinforced concrete construction. We understand that the committee of engineers which has been considering the revision of the Regulations with a view to bringing them more into line with present-day knowledge on the subject has now completed its deliberations, and it is probably in order to obtain first-hand information as to the desirability of making the alterations suggested by this committee that the visit is being made. If the findings of the committee were accepted and embodied in the Regulations one of the most serious impediments in the way of an increased use of reinforced concrete would be removed, and we should be able confidently to look forward to great developments in the near future. We are glad to note, also, that Mr. Topham Forrest is to study American methods of concrete house construction during his stay in that country.

FORMWORK DESIGN.

THERE is probably no item in reinforced concrete construction with more possibilities for waste of material than the formwork, or any item more difficult to estimate. While everything else in the structure is closely studied and exactly specified by the engineer, frequently the whole problem of formwork is left to the judgment of the contractor, and passed on by the contractor to the foreman on the job. In many cases the knowledge of the contractor results in methods as sound and economical as would be produced in the drawing office of the engineer, but this is not always the case. The cost of timber and labour for



[*Mr. T. H. F. Burditt, Architect.*

CONCRETE BUILDING AT BALDOCK: A COLUMN CAPITAL. (*See p.* 557.)

shuttering accounts for such a large proportion of the total cost of a reinforced concrete building, and its proper design and stripping are such important factors in the ultimate strength of the structure, that in the interests of good and economical concrete work the question deserves much more attention than it often receives at present.

No doubt the scanty information readily available on the subject is largely responsible for a lack of interest in formwork commensurate with its importance, for so far as we know there is no book in the English language dealing solely with the subject. In order to fill this gap we have arranged with Mr. A. E. Wynn, B.Sc., A.Am.Soc.C.E., who is well known to readers of this journal by his contributions to our columns, for the publication of an exhaustive treatise on the subject from his pen. Mr. Wynn has been responsible for the design and superintendence during erection of a large number of important reinforced concrete structures of all kinds, especially in the United States, where the question of formwork generally receives much more attention than is often the case in this country, and his treatise is therefore based on much practical experience. The articles will be published in serial form in this journal. The first, given in this issue, is devoted to some general remarks on the subject, while the others contain formulæ for the design of shuttering for every kind of structure and its component parts, and many hints and a great deal of data which have been prepared with a view to simplifying and standardising formwork design.

"VESTED INTERESTS."

WE gather from press reports that the Merthyr Council, which is endeavouring to relieve the shortage of houses by the only means it found practicable, that is, the erection of concrete houses, has received somewhat of a poser in the form of a demand from the local building trade union to return to brick " in view of the fact that there is plenty of available labour." And no doubt the obvious reply of the Council, " Produce the labour and we will consider your request," has put the operatives' organisation in a quandary which leaves no other course open but to allow the matter to drop. Behind this rather amusing, if not amazing, episode there is, however, much food for thought. In their recent joint report both the employers and operatives in the building industry admitted that there is not enough skilled labour in the country to carry out a national housing scheme in addition to ordinary work, and even without a housing programme there are not sufficient bricklayers to meet the present requirements. Yet in spite of these hard facts we find a section of the operatives endeavouring to prevent or delay the erection of dwellings which they themselves need as much as any of their class in other industries. Hardly a day passes but what we see or hear it stated that " vested interests " are holding up house building. Builders are accused of profiteering, manufacturers of materials are stated to be keeping up prices and withholding stocks in order to obtain bigger profits when housing schemes are put in hand, the operatives are charged with restricting output ; but what is to be said of the policy of a body of men whose sole object seems to be to prevent houses from being built at all ? It may be in the " vested interests " of the bricklayers' union to see brickwork used as much as possible, but as they have been promised continuity of employment for fifteen years under Mr. Wheatley's Act, and it is certain that the 2,500,000 houses estimated for can never be produced without a very considerable use of concrete, it cannot be expected that the Government or the public will ever submit to a curtailment of the housing scheme in order that the present generation of bricklayers and their children and grandchildren shall have that continuity of employment which is denied to those engaged in every other trade. If the incident at Merthyr is to be taken as a serious expression of what is in the minds of the operatives, and a foretaste of what we are to expect when the alternative methods of building from which the Minister of Health appears to anticipate so much assistance are attempted, it may not be out of place to state the obvious truism that when the nation wants a thing as badly as it wants houses at the present time it will no more be in a mood to temporise with a small section of obstructionists than with any other " vested interest."

THE MODULUS OF ELASTICITY IN COMPRESSION OF CONCRETE.

By W. D. WOMERSLEY, M.A., B.Sc., Wh.Sch., A.M.Inst.C.E., M.I.Struct.E., A.M.Inst.Mech.E.

In order to determine the elastic constants of a material such as concrete with any degree of certainty it is evidently necessary to work on large specimens in order that the size of the particles of the aggregate shall not be comparable with the dimensions of the test specimen, which may then be expected to behave as a homogeneous mass. Bearing this in mind a test specimen of 2 ft. diameter and 4 ft. length was made up of the following ingredients :—

Portland cement	3 cubic feet	236 lbs. weight.
Ordinary builders' sand containing a considerable amount of chalk	6 cubic feet	544 lbs. weight.
Cambridge flint gravel graded from ¼ in. to ¾ in. and very smooth and rounded	12 cubic feet	1,073 lbs. weight.
Water	12 gallons	120 lbs. weight.

Both the sand and the aggregate were tested for voids with the following results :—

Voids in aggregate 44 per cent. by volume.
Voids in sand 33·2 per cent. by volume.

The materials were thoroughly well mixed by hand in the usual manner, and in addition to the large specimen a number of 4-in. cubes and 3-in. diameter tension specimens were cast for ultimate strength. In casting the large specimen pauses were made about every 6 in. and the material already placed was well rammed. This was very necessary, as the mix was made with almost the minimum quantity of water.

The results of the ultimate tests on the cubes have been as follows up to the present :—

29 days : 2,895 lbs. per sq. in. average of two
79 days : 2,920 lbs. per sq. in. average of three
103 days : 2,930 lbs. per sq. in. average of three.

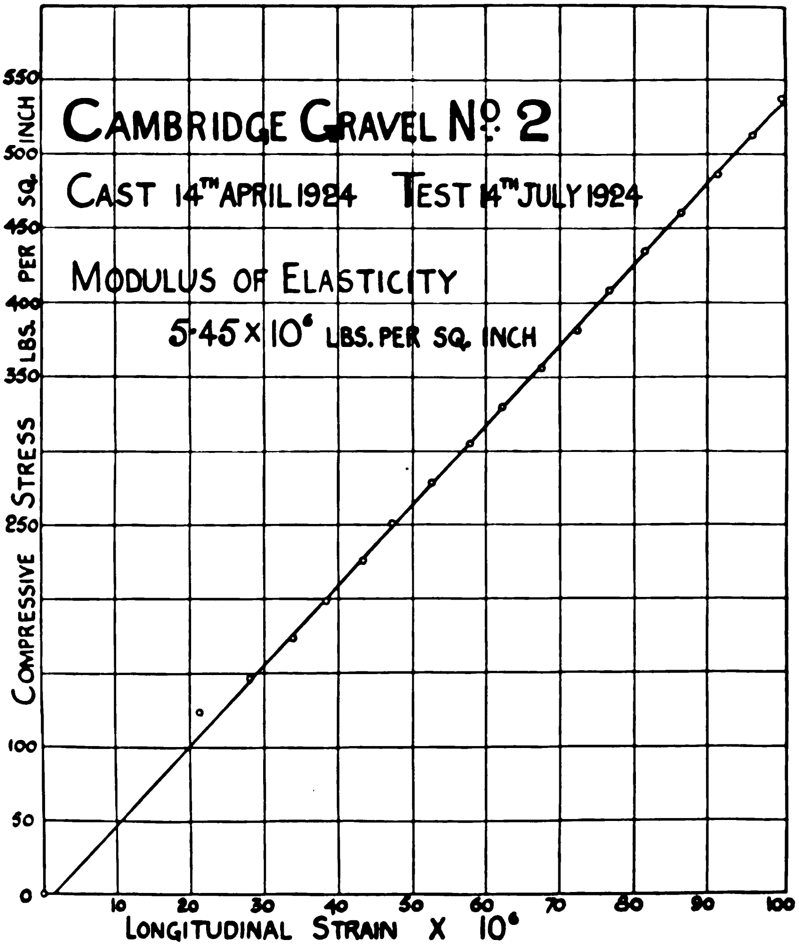
One of the tension specimens was tested and broke at a stress of 174 lbs. per sq. in. at 33 days.

On another day a set of 4-in. cubes and 3-in. diameter cylinders was made, but the same aggregate was screened from ¼ in. to ½ in. ; the ultimate test of this mix was as follows :—

60 days : 3,675 lbs. per sq. in. compression average of six
30 days : 228 lbs. per sq. in. tension, one only.

The large compression specimen has been thoroughly tested in a hydraulic press which was previously accurately calibrated.

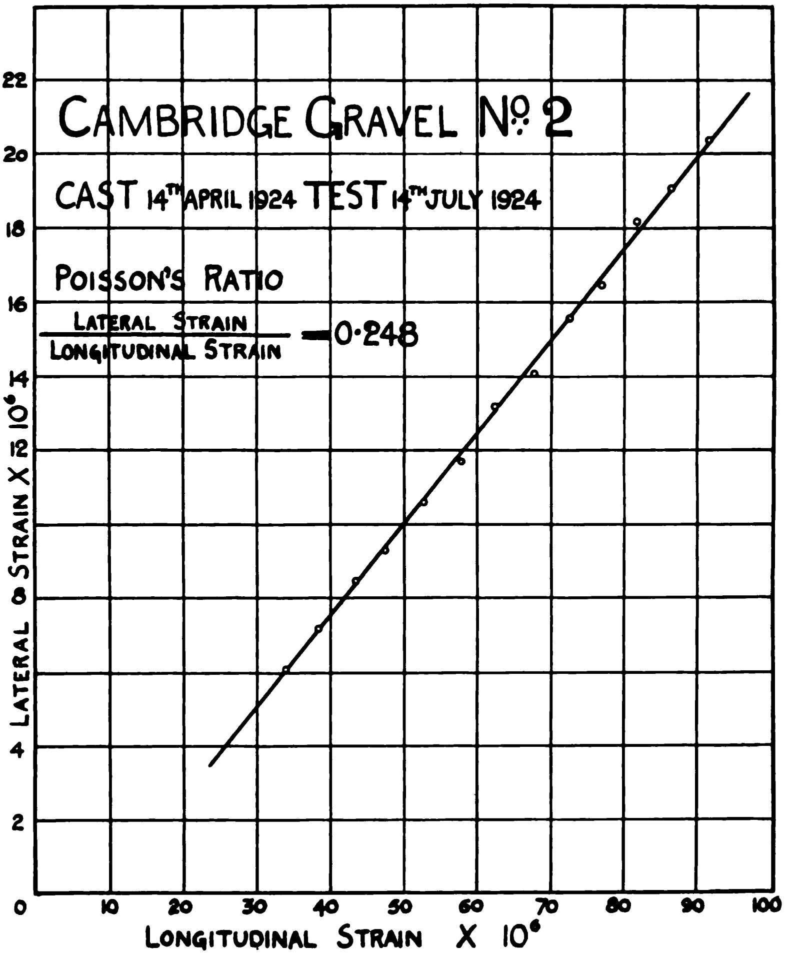
The test length was the middle 20 inches ; heavy iron rings were clipped at the required points, the gripping pads being arranged at the extremities of two mutually perpendicular diameters. Two "Landon" extensometers were used to measure the contraction, and these were arranged at the extremities of a diameter at 45 deg. to the diameters of fixation of the rings. These instruments read accurately to 50,000ths of an inch, and one of them had been calibrated at the National Physical Laboratory just prior to use. Loading and unloading of the specimen was carried out at small intervals between the limits 0 and 538 lbs. per sq. in. The material behaves in a perfectly elastic and regular manner, the relation between stress and strain within the given limits of stress being completely linear. The experiments were carried out in very hot weather, and consequently it was not possible to keep the temperature of the specimen constant. Since such very minute changes of length were being measured temperature changes of even 0·1° C. had considerable effect on the extensometers. The change of temperature was noted by a delicate thermometer placed against the specimen and having its bulb on the air side covered with a layer of about ½ in. of plasticene. Two experiments were made, in one of which the temperature was rising and in the other the temperature falling, the total change of temperature being about 0·4° C. in each case. At the finish of the experiment, when the specimen was unstressed, further temperature strain readings were made



and from these readings the actual stress strain readings corrected. A second pair of experiments were then made, in one of which the temperature rose and in the other fell, the total change of temperature being only 0·15° C. and absolutely the same in both experiments. The averages of the two sets of experiments, the one pair corrected for temperature and the other pair uncorrected, were almost identical.

The averages of the whole four experiments, loading and unloading are given in Table A, and the curve is prepared from them. From this curve the modulus of elasticity is calculated to be $5{\cdot}45 \times 10^6$ lbs. per sq. in., and it is claimed that this figure has an accuracy of the order of 1 per cent. A complete experiment, loading and unloading, took approximately 1¾ hours.

A latometer was devised for measuring the increase in the diameter of the specimen as it shortened in order to obtain Poisson's ratio for the material. This instrument worked fairly satisfactorily whilst the specimen was expanding but would not show the contraction during the process of unloading; also no form



of check on its readings has, as yet, been obtained. The ratio of lateral to longitudinal strain is, however, quite linear and regular once the instrument has commenced to work, and the individual points, being an average of two experiments, are shown in the second curve. From this curve the ratio is calculated to be 0·248. A later experiment, however, in which the latometer was kept vibrating by means of an electric buzzer gives the ratio as 0·289 and in this case there were uniform deflections throughout the loading and, after a slight friction lag, throughout the remainder of the unloading.

TABLE A.

STRESS AND STRAIN FOR 1 : 2 : 4 CONCRETE AT 90 DAYS.

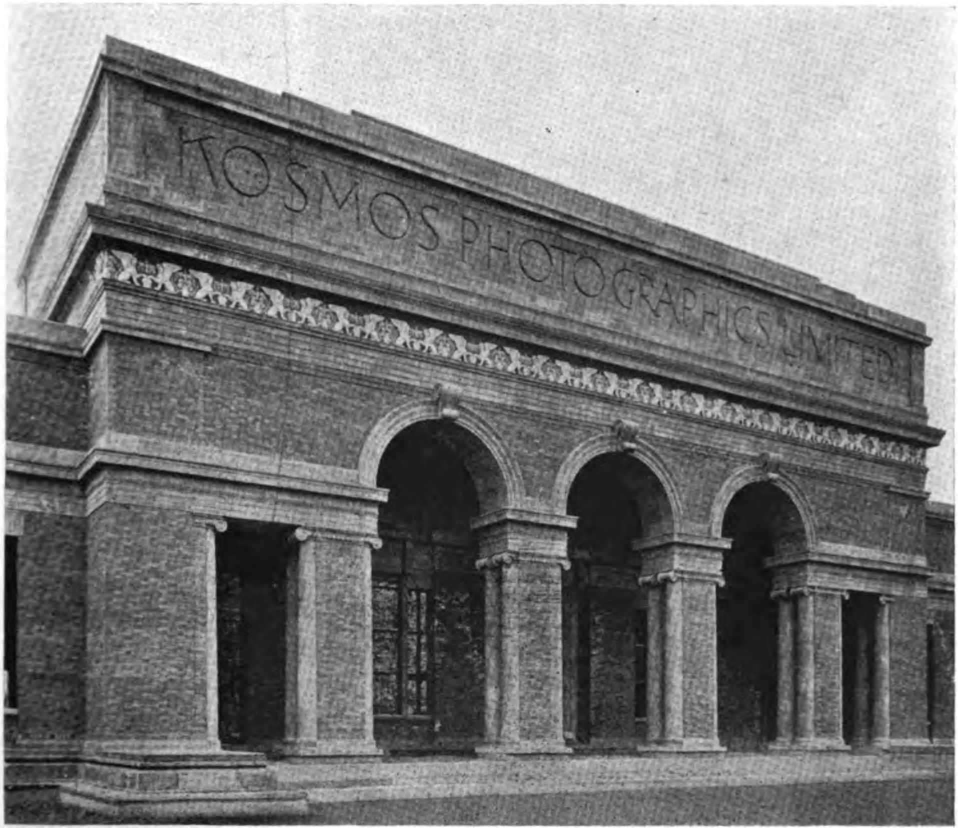
Stress lbs. per sq. inch.	0	121	147	173	199	226	251	278	305
Longitudinal strain × 10^6.	0	21·2	28	33·7	38·2	43·2	47·1	52·5	57·7
Lateral strain × 10^6	—	—	—	6·1	7·2	8·5	9·3	10·6	11·7
Stress lbs. per sq. inch.	330	357	382	409	435	461	487	513	538
Longitudinal strain × 10^6.	62·2	67·5	72·4	76·8	81·5	86·3	91·4	96	99·7
Lateral strain × 10^6	13·2	14·1	15·6	16·5	18·2	19·1	20·4	—	—

The above experiments were carried out in the Engineering Laboratories of Cambridge University as a preliminary to a more extended series at present about to be commenced in order to ensure the satisfactory working of the apparatus. The results have been given at once on account of the very high value obtained for the modulus of elasticity, especially as the materials used and the method of mixing are not considered the best possible for reinforced concrete work.

A CONCRETE FACTORY BUILDING.

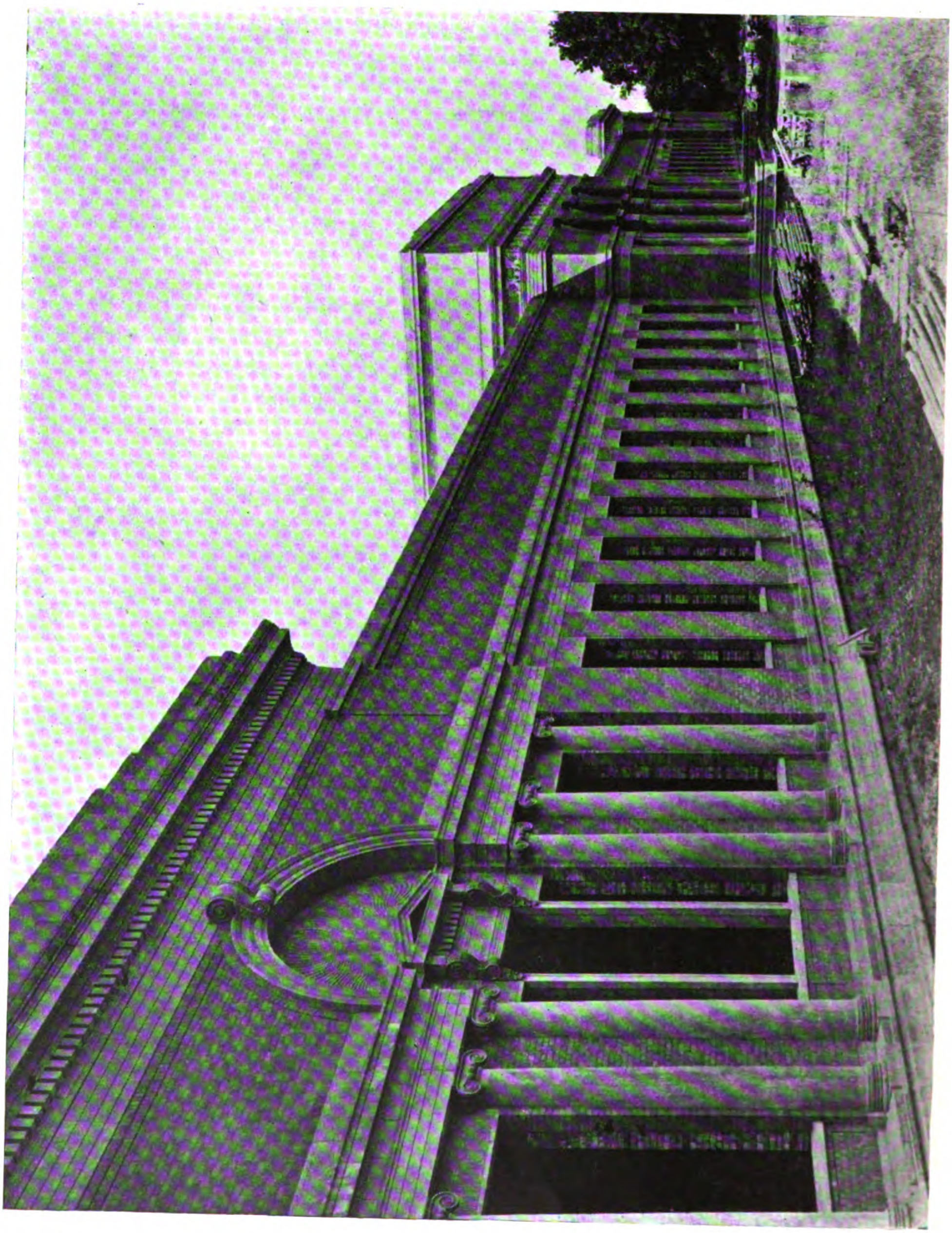
In the pleasant country town of Baldock in Hertfordshire, an old-world town which except for a post-war housing scheme on its borders seems to have altered hardly at all during the past hundred years, a building is now nearing completion which we venture to think will be looked upon as one of the turning points in the development of the design of concrete buildings in this country. It is a factory building designed by Mr. T. H. F. Burditt, architect, of No. 10 Grafton Street, W.1. We make no apology for giving so many illustrations of this building, which might be left to speak for themselves, except that the architect has successfully applied many interesting theories in the design and many ingenious methods and contrivances of construction which should be of great interest to all concerned with the future of concrete in architecture.

Undoubtedly the site is a good one, lying back from the main road in well-wooded park land sloping upwards from front to back. It was thus possible to provide a green-covered slope along the whole of the front of the building, broken in the centre to allow of a broad flight of steps up to the main entrance. The total

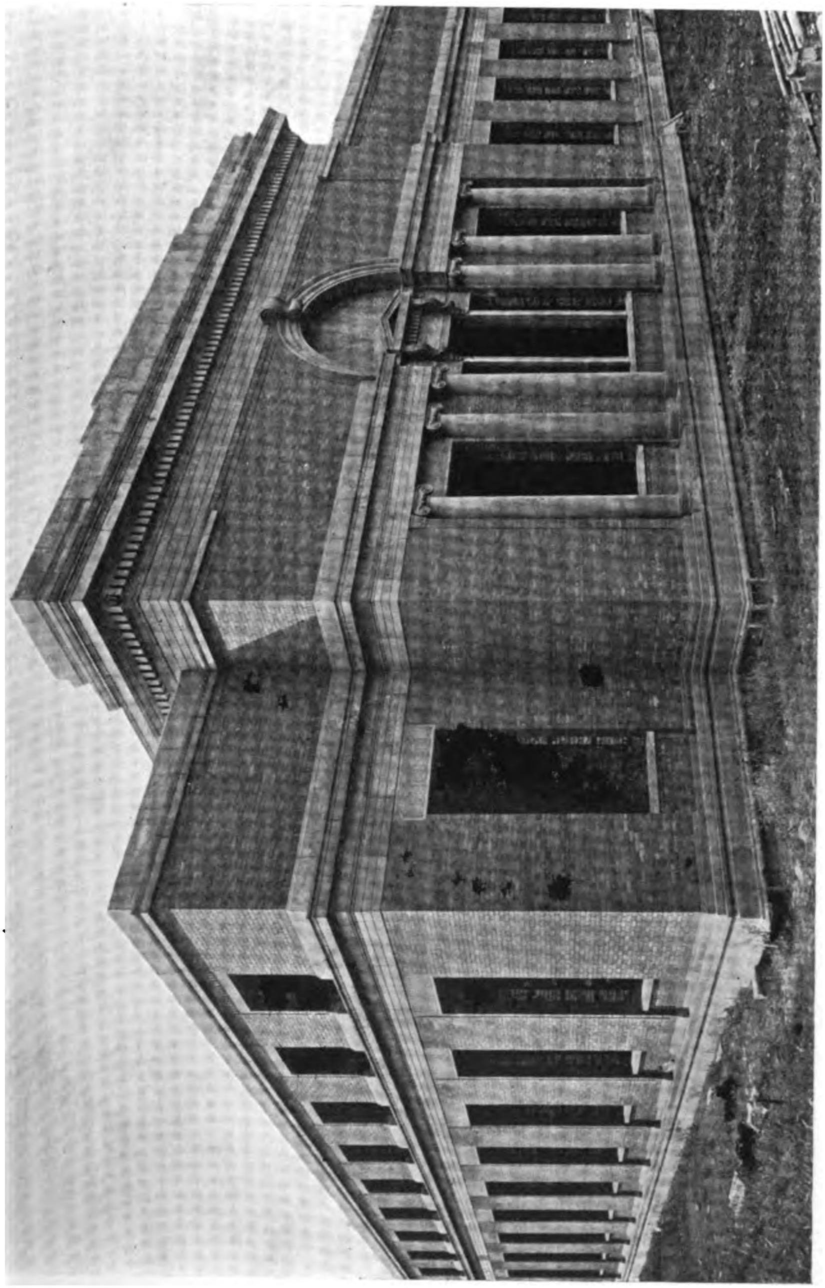


[*Mr. T. H. F. Burditt, Architect.*

CONCRETE FACTORY BUILDING AT BALDOCK: MAIN ENTRANCE.

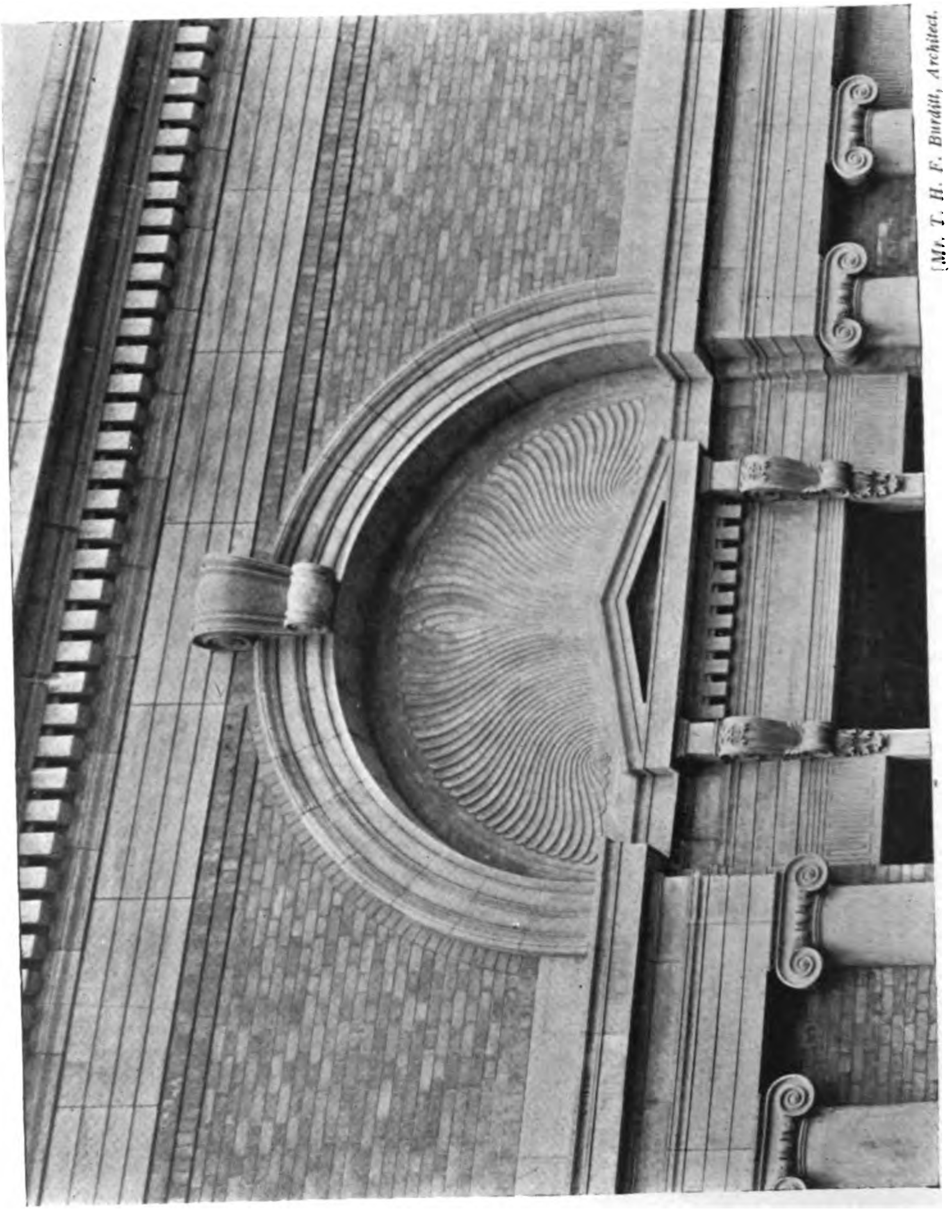


CONCRETE FACTORY BUILDING AT BALDOCK: GENERAL VIEW OF FRONT ELEVATION. [Mr. T. H. F. Burditt, Architect.



[*Mr. T. H. F. Burditt, Architect.*

CONCRETE FACTORY BUILDING AT BALDOCK: VIEW OF ONE OF THE END FEATURES AND SIDE ELEVATION.



[Mr. T. H. F. Burditt, Architect.

CONCRETE FACTORY BUILDING AT BALDOCK: DETAIL.

length of the building is about 500 feet, relieved by a central feature and end features.

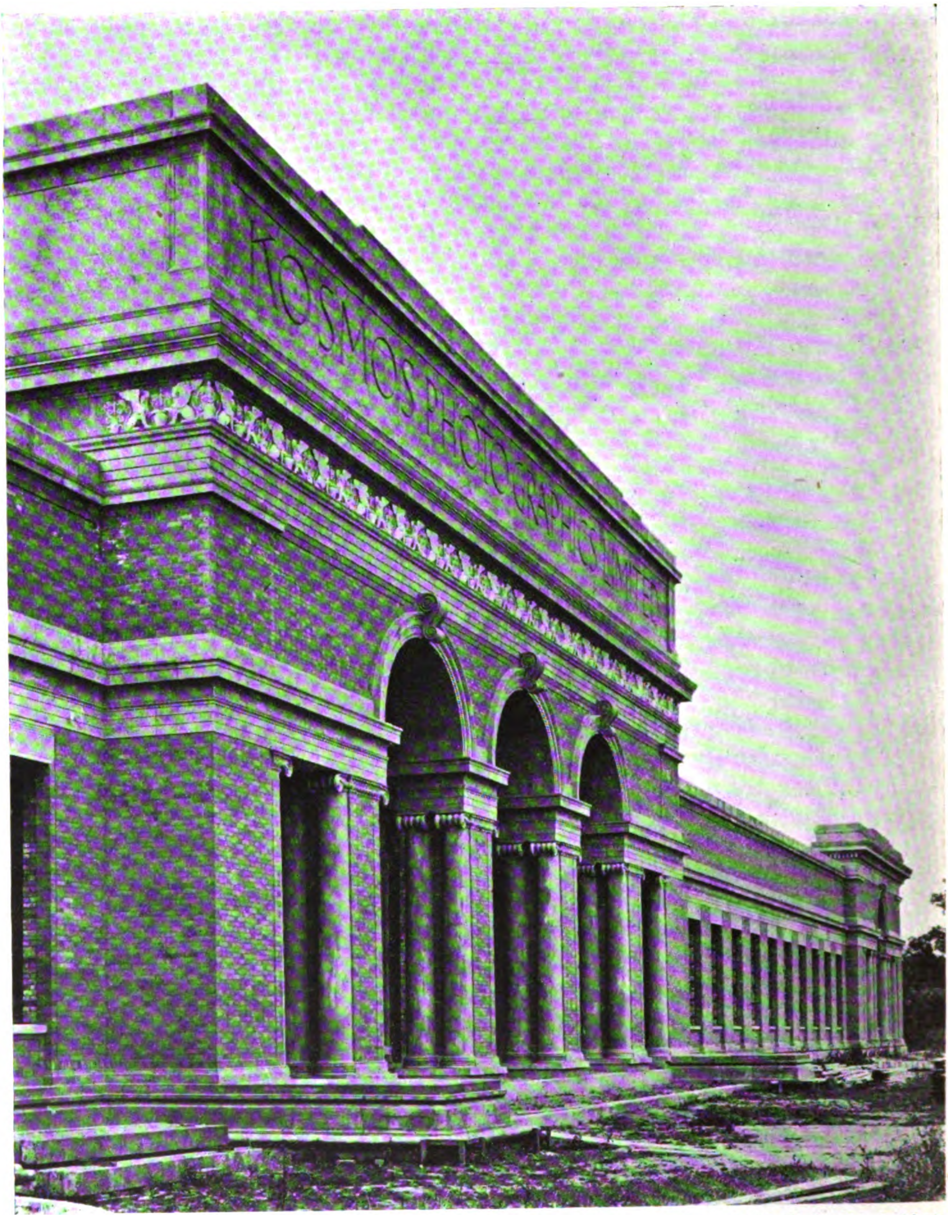
The whole of the building is of concrete with the exception of interior curtain walls, which are of Fletton bricks. In spite of its appearance, the whole of the façade is of concrete cast in the form of bricks, columns, stringcourses, mouldings, and decoration. The absence of windows to the upper story (the building comprises basement, ground floor, and first floor) is due to the fact that this floor is given over to the dark rooms necessary for the manufacture of photographic goods, and no doubt influenced the design of the front elevation.

The design is Renaissance in character, but the details more closely follow the original classical models. A practice of ancient Greek architects has been reintroduced of building all horizontal lines in slight curvature, and in this case all horizontal lines, including floors, have an upward curvature measuring 5 in. at the centre over an imaginary chord joining the extremities of the building. The effect is not intended to be obvious, but the building in slight curvature lacks the rigid and mechanical effect of the hard straight line. Also, the external faces of all the walls have a slight batter, inclining from the perpendicular about 1 in. in 12 ft., thus giving an added effect of stability. The building was not quite completed when our photographs were taken, but we also give the architect's drawing of the front and back elevations. The four lamps over the doorway are an essential feature of the design.

The concrete bricks were made by hand in wooden moulds divided so that five bricks were produced on each pallet. The mixture was used as dry as would permit of workability, and it was thus possible to release the moulds immediately and on the following day to remove the bricks from the pallets, which were then ready for re-use. The cost of these concrete bricks, which were made at the rate of 1,000 per day, worked out at less than the current price of good facing bricks, representing a very considerable saving on a building of this size.

The whole of the column capitals and bases, key stones, architraves, arches, stringcourses, etc., were cast from plaster moulds made from the architect's drawings in his own studio. The utmost forethought and care have been given to every detail of the casting of these features, and the result is the production of moulded concrete which for clean surfaces, sharp definition, and freedom from hair cracks or blemishes of any kind could hardly be improved upon. An idea of the attention given to this operation may be gathered when it is stated that in order to avoid any air bubbles in the concrete as it left the mixer from affecting the surface of the castings it was poured into pails and stirred until the air was released and then lowered to the bottom of the mould in a small vessel and gently placed in position, further concrete being added to fill the mould so that it did not disturb that already in position. In all the moulded concrete used on the elevations of the building, projections were cast at the back so that the ornaments could be firmly grouted into spaces left for them in the wall.

None of the moulded concrete was cast *in situ*. The capitals of the columns were cast separately, and the shafts, with bases, which are 16 ft. in height, were cast in one piece horizontally and afterwards hoisted into position. Owing to the fact that the columns were more than half a diameter they could not be withdrawn from a jointless mould. A strong concrete trough-shaped mould was therefore made a little larger than the required column, and this was then



[*Mr. T. H. F. Burditt, Architect.*

CONCRETE FACTORY BUILDING AT BALDOCK: PART OF FRONT ELEVATION.

lined with a plaster waste mould, run in by means of a template. The reinforced column, after seasoning for a fortnight, was removed with the waste mould intact and the latter was then cleared away, leaving the column free from joints. The concrete mould was then re-lined with a new waste mould for the next column, of which there are thirty-two in all.

Wooden moulds were used for the base course, but everything above that was cast in plaster.

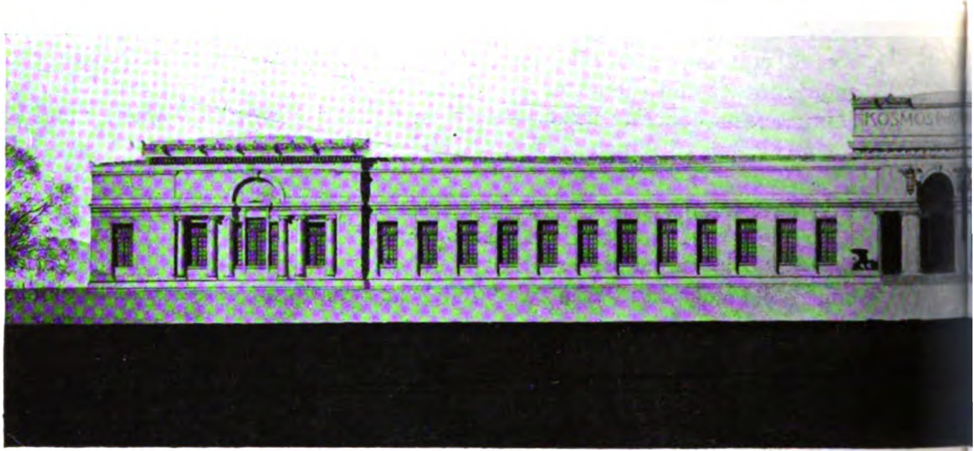
The lettering over the main entrance was specially drawn by the architect on plaster in actual size, so that the lines would not clash with the joints of the concrete blocks, and was carved in plaster. From these models moulds were taken from which the concrete blocks containing the lettering were cast.

The frieze over the main entrance is of special interest and shows what can be done in this direction. Although full of delicate moulding, it has been so carefully executed that there is not a ragged line or a clogged detail to be seen. The figure of a winged lioness with a female head is the trade mark of the owners of the building, Messrs. Kosmos Photographics Limited, and this the architect has developed into the *motif* shown in the detail on p. 566. A white cement was used for the frieze, and this shows up exceedingly well on a deep red background.

The whole of the façade is coloured, and the delicate mauve-grey shade, varied and interesting, obtained at no expense whatever for colouring materials, is an effective answer to critics who complain of the monotonous appearance of a concrete building when the grey cement only shows on the surface. The building is erected on the site of an old red-brick house which had to be demolished, and the old bricks have been used to form aggregate and at the same time supply the colour for the whole of the façades, both for the concrete bricks and the moulded features. For the bricks the concrete was generally composed of 1 part Portland cement, 3 parts sand, and 1 part of crushed red brick, the proportion of crushed brick being slightly varied in order to obtain differing shades in the bricks and relieve the walling from the uninterestingness which must have resulted had they been all exactly alike. For the cast decoration the concrete was made of 1 part Portland cement, 2 parts sand, and 1 part crushed red brick. Here again the proportion of crushed brick is varied slightly in individual castings, and an interesting surface obtained. The larger proportion of water in the decorative features gives them the slightly richer tone necessary to make them stand out from the remainder of the façade, and is typical of the attention to detail so noticeable throughout the building. The background to the frieze is formed of blocks in which no sand is included, the larger proportion of red brick dust providing the deepest tone on the building and making an admirable setting for the white figures.

None of the concrete whatever has been touched with a tool after it left the moulds.

The general construction of the building is reinforced concrete floors carried on reinforced concrete columns and beams. The ground floor is poured; the first floor is of Siegwart beams. The roof is of concrete without any covering, a topping of 2 in. of a 1 : 3 mixture of cement and sand forming a dense concrete which has proved to be absolutely waterproof. Expansion joints are provided every 20 ft. in each direction. The roof is carried on girders 20 ft. deep, and a number of these have been cast with aqueducts throughout their length and thus



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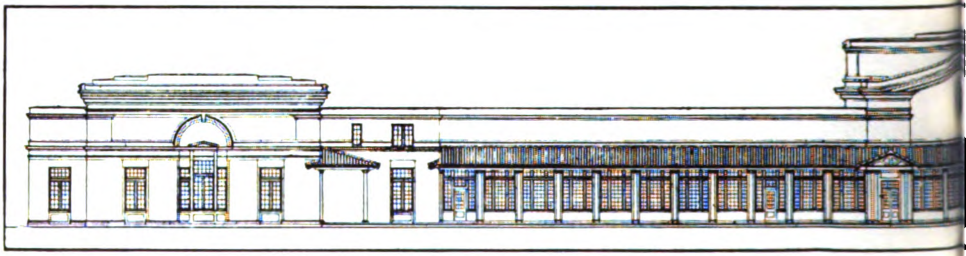

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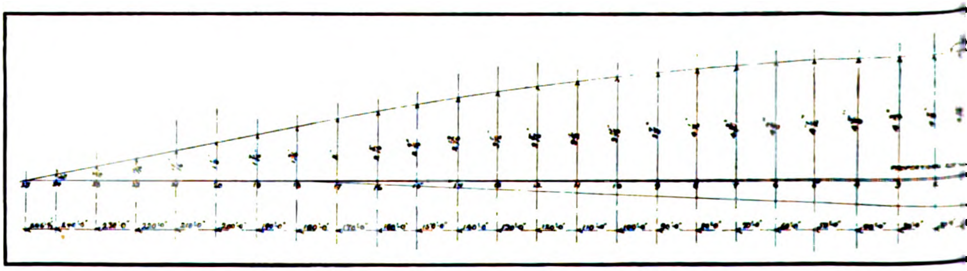
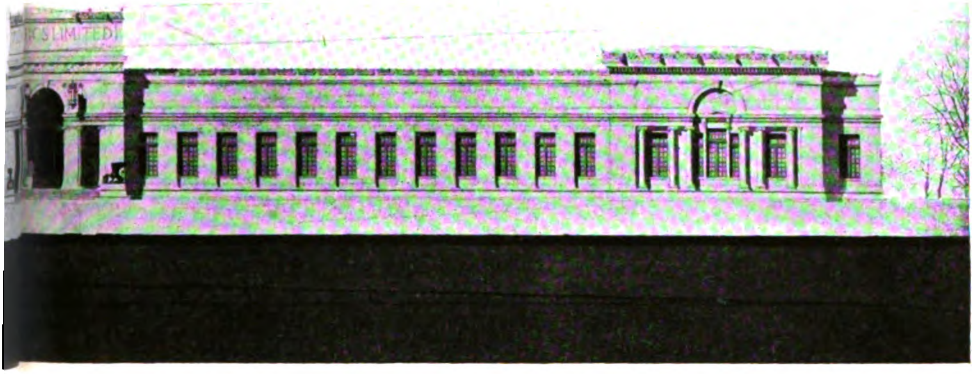


Diagram of Curvature of Elevation: The

CONCRETE FACTORY



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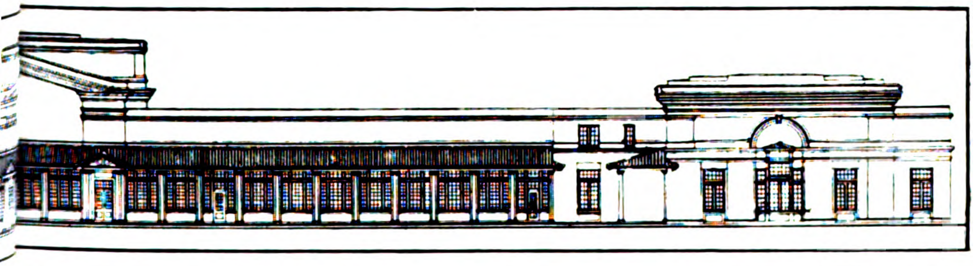

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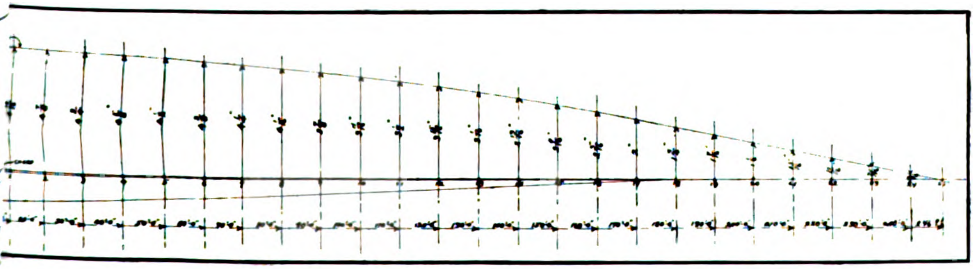
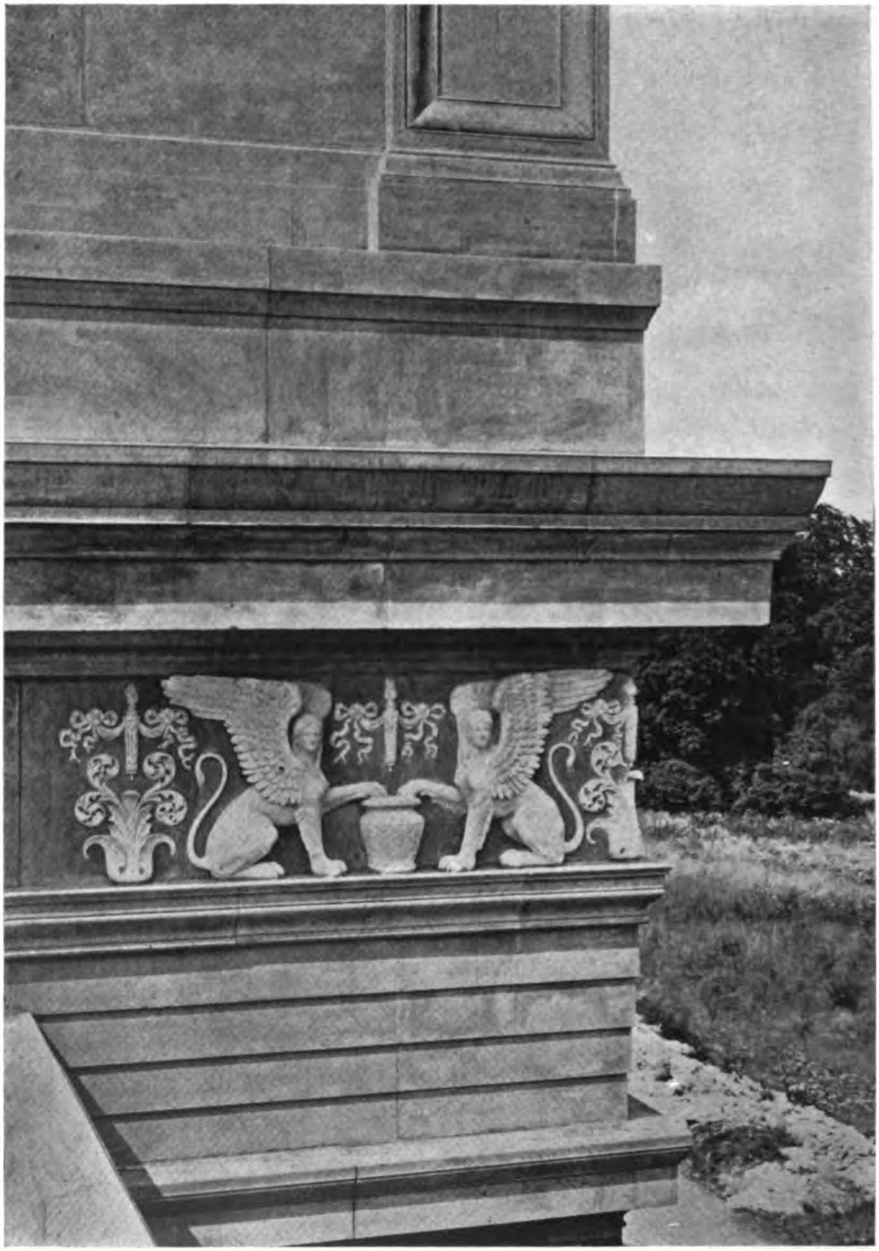


AL SCALE IS 96 TIMES THE HORIZONTAL SCALE.

NG AT BALDOCK.

[Mr. T. H. F. Burditt, Architect.



[Mr. T. H. F. Burditt, Architect.

CONCRETE FACTORY BUILDING AT BALDOCK: DETAIL OF FRIEZE OVER MAIN ENTRANCE.

also act as a roof drainage system by carrying the water to the downpipes arranged in the internal walls, an economical device not generally adopted in this country.

Comparing this imposing structure, possessing a dignity worthy of almost any site, with the ordinary factory building one is inclined to wonder why the owners have invested in an expensive factory in a small country town where at present it is almost hidden from the road by trees. We are informed, however, that the building, with a basement and two stories above ground, covering an area of 50,000 superficial ft. on each floor, and with much intricate interior constructional work, has only cost about 11*d*. per cubic foot as it stands to-day, and that when completed it is not expected to cost more than 1*s*. 2*d*. per cubic foot including all fittings and decoration. Truly concrete, in capable hands, has enormous possibilities for the production of beautiful buildings, buildings which will be a pleasure to live with and to work in, buildings which will cost no more than the cheap and often ugly industrial buildings which have been allowed to disfigure our towns and countryside in the past. Mr. Burditt, who has had considerable experience in designing in plastic materials (he was, by the way, architect for the California building at the San Francisco Exposition, in which a great deal of plaster enrichment was used) is to be congratulated on having produced a building which should do much to dispel the myth that concrete cannot be beautiful. One criticism which might be made is that the building is too monumental for its purpose as a factory, that it expresses an art gallery or public library rather than an industrial building, but it has to be borne in mind that the business of the firm is closely allied to art and as a matter of fact the large entrance hall reached through the colonnade at the main entrance is to be used as a gallery in which will be displayed photographs made with the products of the firm. Moreover, the maximum window space which is a necessity with most factory buildings was not required here owing to the nature of the work to be carried on, and the opportunity thus presented has been taken full advantage of by the architect.

DESIGN OF FORMWORK FOR REINFORCED CONCRETE CONSTRUCTION.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

1.—FORM BUILDING IN GENERAL

EVERY kind of reinforced concrete construction requires first of all the building of moulds in which to pour the concrete. These moulds, or, as they are termed, " formwork " or " shuttering," are therefore a very essential part of the concrete contractor's work. If he is experienced in this class of work the formwork will present no especial difficulties, as he will have developed a system of his own, worked out from his years of experience. But to the contractor who is just going in for this kind of work, or who only gets a concrete job occasionally, and to the owner who does his own construction, the method of designing and building the forms may not be familiar.

If there were a more universal knowledge of formwork erection there would be a greater use of reinforced concrete construction. Firms who have always used brick and steel in their construction work often have a prejudice against reinforced concrete because they feel they cannot get workmen familiar with form building, and that therefore the finished structure will either not look well or will cost too much money.

It is mainly for those who are unfamiliar with the subject that these articles are written.

General Remarks

There is very little literature on the subject, and probably no book in the English language devoted entirely to it. Being temporary and not permanent construction, it has always been left to the individual to develop his own methods.

However, reinforced concrete has been in use for so long now that the best of these methods have become standardised with firms who specialise in this construction. Although the general principles have been standardised, each foreman will probably have his own special preference for details. It is impossible to write about all the details of construction, because new ideas are being worked out every day, but there are certain details that are essential.

There is one best way to build any form, and that way is to use the timber available to the best advantage, having each member of the structure correctly proportioned to carry its part of the load with no waste of material, at the same time giving attention to a few construction details that will facilitate erection and stripping of forms.

Unskilled Work

Lack of knowledge, and hence unskilled work, has often led to the collapse of a building. Lack of sufficient bracing and shoring, the use of timber not sufficiently strong to carry the loads, stripping too soon, etc., have caused many failures.

Even if there is no failure the work will look bad and be a poor advertisement for this type of construction. Bulges in walls, sags in floors, wavy lines in beams and columns, and fins and ridges on the finished concrete are all due to unskilled knowledge of how to build the forms correctly, and can be avoided. Then there is the expense to the contractor who has to make good his work, no easy task after the concrete has once been poured.

Form Builders

Specialist firms have some carpenters who do nothing but this class of work, and so have become experienced in the methods and details. This is as it should be. Form building is a trade of its own, and there are good opportunities for carpenters who are willing to train themselves in this class of work.

Since formwork is such an important part of concrete construction, by far the majority of concrete construction foremen are carpenters by trade.

The carpenter who is only used to indoor and finished work, however skilled he may be, is of little use in building forms, as it will take him a long time to realise that he is not building a permanent part of the work. He will waste so much time in accurate fitting and drive in nails that the only way to strip the forms will be with an axe.

Inexperienced contractors, whenever possible, should always employ two or three experienced form builders if they wish to produce rapid building.

Inspection

When the forms are built ready for concreting they should always be carefully inspected by the architect or engineer, who should know the essential points to look for and should be able to tell at a glance if the work is satisfactory and able to carry the loads.

The carpenter foreman, in the rush of the work, will often overlook some important detail, leave out a brace or shore, forget to straighten up his lines, omit some tie wires, etc., with resulting sags and bulges and poor lines, if not failure.

During concreting, too, it is specially important to have at least one carpenter watching the forms, tightening wedges, adding braces, looking for weak spots, on the alert all the time for emergencies. " Prevention is better than cure " is especially true of concrete work, and many weak places have been rectified in time by this means. It will be too late after the concrete is poured.

Economy

The foregoing remarks will all lead to economy, but there is also economy in design.

Design should not be left to the individual foreman or carpenter, unless he is very experienced, as he seldom has a knowledge of the mechanics of materials. He may, through years of experience, choose the right size and spacing of timbers to carry the loads, but it is more by good luck than good management, and he has probably had to learn through his mistakes.

It is almost always the case when something out of the ordinary is to be constructed, with extra heavy loads, that if the design is left to the field organisation it will be too weak. The size and spacing of joists, girts, studs, shores, yokes, wales, etc., should always be worked out in the engineer's or contractor's office. This will lead to the greatest economy in material.

The details of framing can be left to the practical mechanic in the field, who, however, should be taught and trained in the observance of the essential points.

Economy in stripping is very important. However well a form may be built its ultimate success depends upon the speed and ease with which it can be stripped. This is a point which is often overlooked, and it is here that most of the essential details of framing occur.

The economy of being able to use the timber over and over again is obvious. The success of this, however, depends on the original design and method of framing. When making the design it is necessary to look ahead and observe how many times the timber can be used over again, and what changes will be necessary. This means unit or panel construction.

If the formwork for the first floor of a building is so built that it has to be all torn apart to build the second floor there is no economy. The first floor should have been built, as far as possible, in units that could be used on the second floor with few or no changes.

Stripping

Experience will tell how long to leave the forms before stripping, but in general this should be decided by the architect or engineer. It will depend mainly upon weather conditions, and will vary with different parts of the structure. The knowledge of how to re-shore after stripping is very important when speed is necessary, and it is usually important for economy. The experienced contractor who can reshore without bringing any strain on the green concrete can be allowed to strip much earlier than a contractor who has not had that experience.

If reshoring is to be necessary it must be allowed for in the design, which must be made so that certain shores can be left in place while the rest of the forms are stripped. Too many failures have resulted from wrong stripping to allow it to be left to chance.

Systematisation

On big work, and small work if the workers are inexperienced, the design should be made in the office by an experienced man, and all the main forms detailed on paper and given out to the foreman. This will ensure economy and adequate strength, and will relieve the foreman of much responsibility and detail work and enable him better to look after the actual execution of the work.

It will also lead to systematisation, using the same methods on different jobs, after, of course, the method has been proved to be the best. It will save endless argument with foremen, who generally wish to build the forms in their own way.

Better costs can be kept and better comparisons made between foremen and different gangs of carpenters when they are all following the same methods.

It is a great advantage for a foreman to be able to give the carpenters a sketch and tell them to " make up so many of these panels, column or beam sides, etc." With no system the foreman will be running all over the job, and the carpenters will be standing still wanting to know what to do next.

Of course the man in the office, who makes the design, must also have a knowledge of how the forms are erected.

Framing Details

Besides the main features of design there are many practical tips that are learnt by experience. Some of them have become standard practice and will be mentioned later.

An ingenious workman can save much money for his employer by discovering better methods of executing details.

Ordering Material

Material should be ordered in the office and not on the job. Haphazard ordering of timber leads to waste. However much timber is sent to a job it will always be used up, as a carpenter will always choose new timber in preference to old. Even with careful economy on the job there is usually more timber used than estimated.

From experience or detail drawings the bill of material can be taken off and just the right amount ordered allowing for waste. The foreman should be told how much he is allowed for the job, and he will then exercise economy. The timber should not be sent to the job all at once, or there will undoubtedly be waste.

Cost

The cost of formwork is the most difficult part of a reinforced concrete structure to estimate.

Unless a system is adopted the costs may vary enormously with different workmen. They vary greatly, too, with the carpenter-foreman, for one man may be able to get twice as much work out of the men as another and he may also be able to plan his work better.

Systematic design and planning of the work on the job are the only things that will keep down costs.

As far as possible the number of man-hours required to perform various operations will be given. They cannot, of course, be exact and must only be used as a guide to estimating. Man-efficiency has enormously decreased since the war, and during the last few years it has been difficult to estimate how much a man would accomplish in a given time.

Old data on costs are quite unreliable now, and the only right method is for each contractor to keep his own costs and work out his own cost units. Cost keeping is a problem in itself, but it cannot be stressed too highly, especially on this class of work, if the contractor wishes to come out on the right side.

In estimating concrete work the job should be analysed into its component parts and each part priced separately at so much per square or lineal foot. Estimating formwork at so much per cubic yard of concrete or at so much per square foot of floor area, as is often done, although it forms a check on more detail calculations, may lead to serious losses.

General Requirements

Strength is the first requisite ; the forms must be strong enough safely to carry the dead load of the concrete plus a live load applied during concreting.

Durability and rigidity are of next importance ; the forms must be stiff and able to withstand hard and repeated usage. Lines must be true, bulges and sags must be prevented.

Cheapness, consistent with strength, is what the contractor is interested in. This means economy of material and correct construction details.

Economy in treatment of the concrete surfaces depends upon the tightness with which the forms are built, preventing ridges and fins, which afterwards have to be chipped off, caused by seepage through cracks.

Engineer's Design

Although the engineering design of the structure is not the concern of the form builder, for true economy it should be made in conjunction with him. If the builder and designer are the same firm there is no difficulty in this.

If, however, an independent engineer or architect makes the structural design he cannot consult beforehand with an unknown builder. He can, however, make his design so that the form construction will be of the simplest.

A very small change in design often results in large savings in the cost of forms. A little extra concrete is usually cheaper than changing forms to save concrete. As few changes as possible in column and beam sizes from floor to floor means a great saving in labour.

Where live loads decrease on the upper floors of a building it is generally better to keep the beam sizes below the slab the same as on the heavier floors.

Suiting the design to the commercial sizes of dressed timber is rarely done, though it can be just as easily as not. It is common practice, for instance, to give beam widths in even inches, while dressed timber will make up into widths of odd inches with perhaps a fraction over.

This does not matter if the engineer will accept a beam width that is perhaps an inch less than specified, but he rarely will, and should not do so unless allowed for in his design. For a beam specified as 12 in. wide it would require a beam bottom made of a 2 in. by 12 in. dressed to, say, 11½ in. with the addition of a ½-in. strip, or it would require two 2 by 6's dressed to, say, 5½ in., giving a total width of 11 in., with the addition of a 1-in. strip. The design could have been made so that a width of 11 in. would be sufficient, and so save piecing out.

Similarly, a beam specified as 8 in. wide should be 7½ in. so that 2 in. by 8 in. dressed timber could be used.

Much time and labour are spent in filling out to meet even dimensions because the designer had not thought of economy in forms. Many designs are made which may be perfectly good from an engineering standpoint but which are costly in form building.

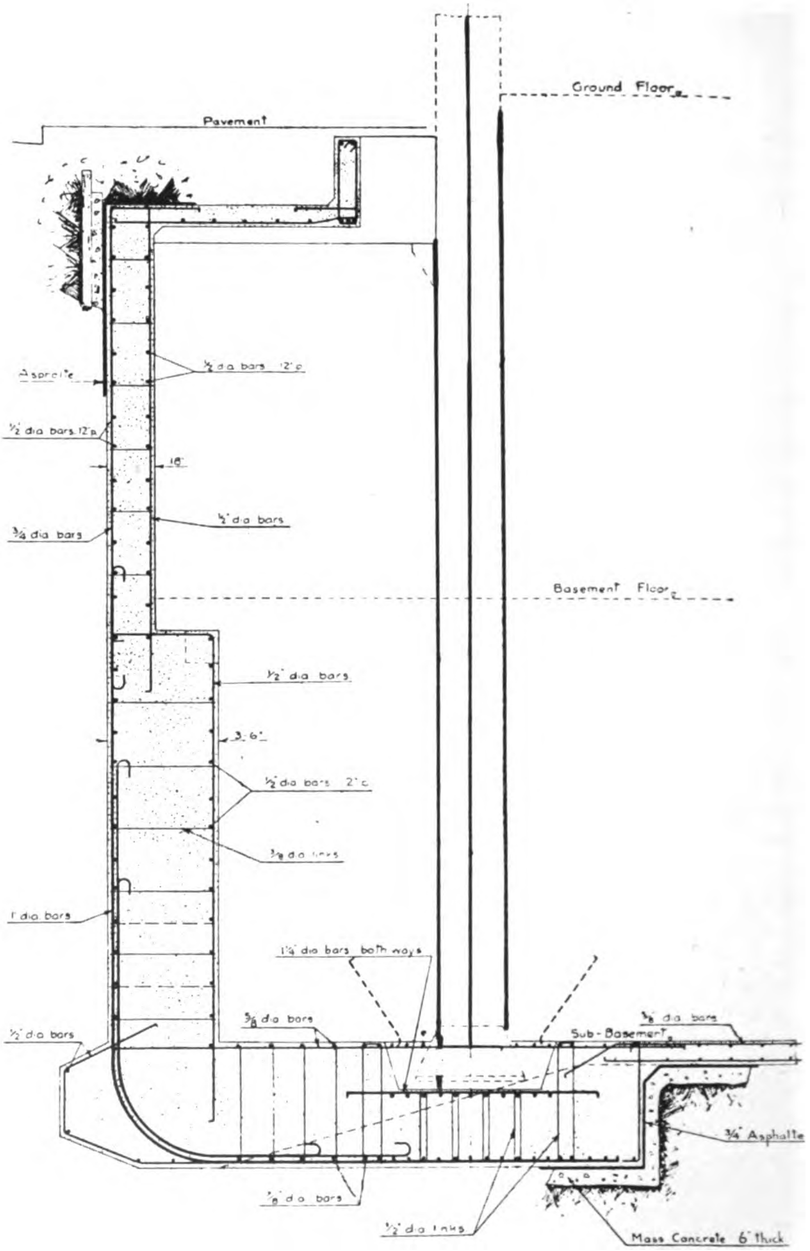


FIG. 1.—CROSS-SECTION OF RETAINING WALL AND ADJACENT STANCHION-BASE.

REINFORCED CONCRETE SUBSTRUCTURE AT MESSRS. JOHN BARKER'S NEW BUILDING.
(*See p.* 575.)

REINFORCED CONCRETE SUBSTRUCTURE FOR MESSRS. JOHN BARKER'S NEW STORE AT KENSINGTON.

By W. L. SCOTT, A.M.Inst.C.E.

THE substructure of the new store for Messrs. John Barker & Co., Ltd., contains retaining walls and foundations in reinforced concrete of more than usual interest. In fact, these portions of the structure are probably the most interesting features of what, when finished, will form one of the finest examples of a modern store existing in this or any other country.

Apart from the height of earth supported by these retaining walls, amounting to 31 ft., water had to be contended with, this giving a hydrostatic head above the sub-basement level of 5 ft. In addition to this, buildings had to be supported on two sides of the site, and the Kensington High Street, with its heavy vehicular traffic, along the front. It was also necessary, owing to the height of these walls, to design them so as to be entirely self-supporting, since the shoring that would have been necessary to support them until such time as the two floors were erected and giving lateral support was impracticable.

The total horizontal thrust of earth sustained by the four walls amounts to approximately 4,000 tons, and the design of the walls is such that this huge pressure, combined with the vertical loads coming upon them, imposes a pressure within that permissible upon the quality of clay on which these foundations repose.

A typical cross-section of the walls is given in *Fig.* 1, and a plan at basement level, showing the general arrangement of the walls and foundations, is given in *Fig.* 2 (see page 580).

The reinforced concrete foundations carrying the main stanchions carry a maximum load from these members of 612 tons, and arrangements have been made for the subsequent reception of the steel bases by means of pockets recessed into the reinforced concrete work, so that the gusset plates to these steel bases, etc., do not project above the finished basement floor level.

In order to prevent any possibility of percolation of water from the outside, the whole of the reinforced concrete work below ground level is protected by a coat of asphalte comprised of two layers, each ⅜ in. thick. Upon the outside of this again is a layer of mass concrete 6 in. thick, which has been introduced to form a proper surface for the reception of the asphalte lining and to keep out any water during this important operation.

These precautionary arrangements, devised by the architect, Mr. H. L. Cabuche, O.B.E., F.S.Arc., in conjunction with the consulting engineers, Messrs. Considere Constructions, Ltd., were carried out by the contractors for the work with complete success, and in a very workmanlike and expeditious manner.

A considerable amount of underpinning and other devices necessary to support the foundations of the existing buildings mentioned above has been satisfactorily carried out in reinforced concrete.

The raft slab for the basement floor to the building, in addition to its function as a floor, is designed to resist an upward pressure of some 3,500 tons resulting from the head of water above mentioned. It is admittedly doubtful, owing to

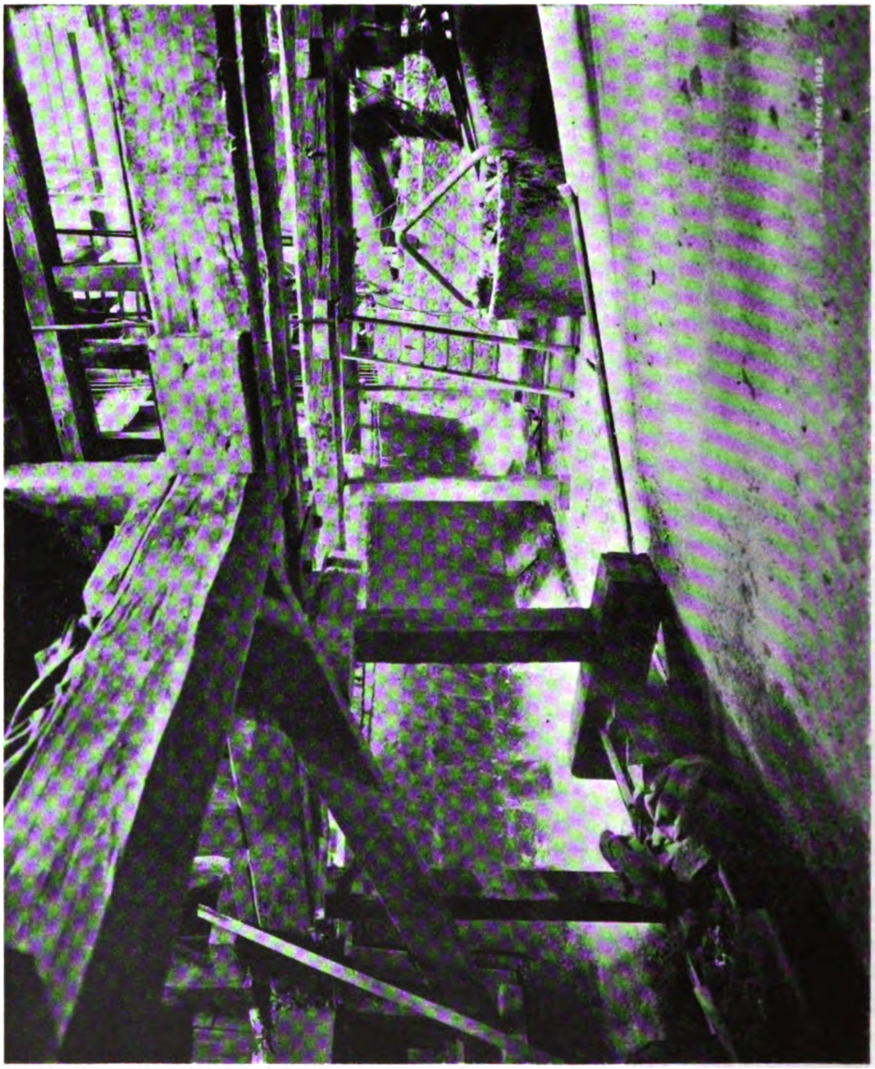


FIG. 3.—ASPHALTED SURFACE READY FOR CONCRETING.

REINFORCED CONCRETE SUBSTRUCTURE AT MESSRS. JOHN BARKER'S NEW BUILDING.

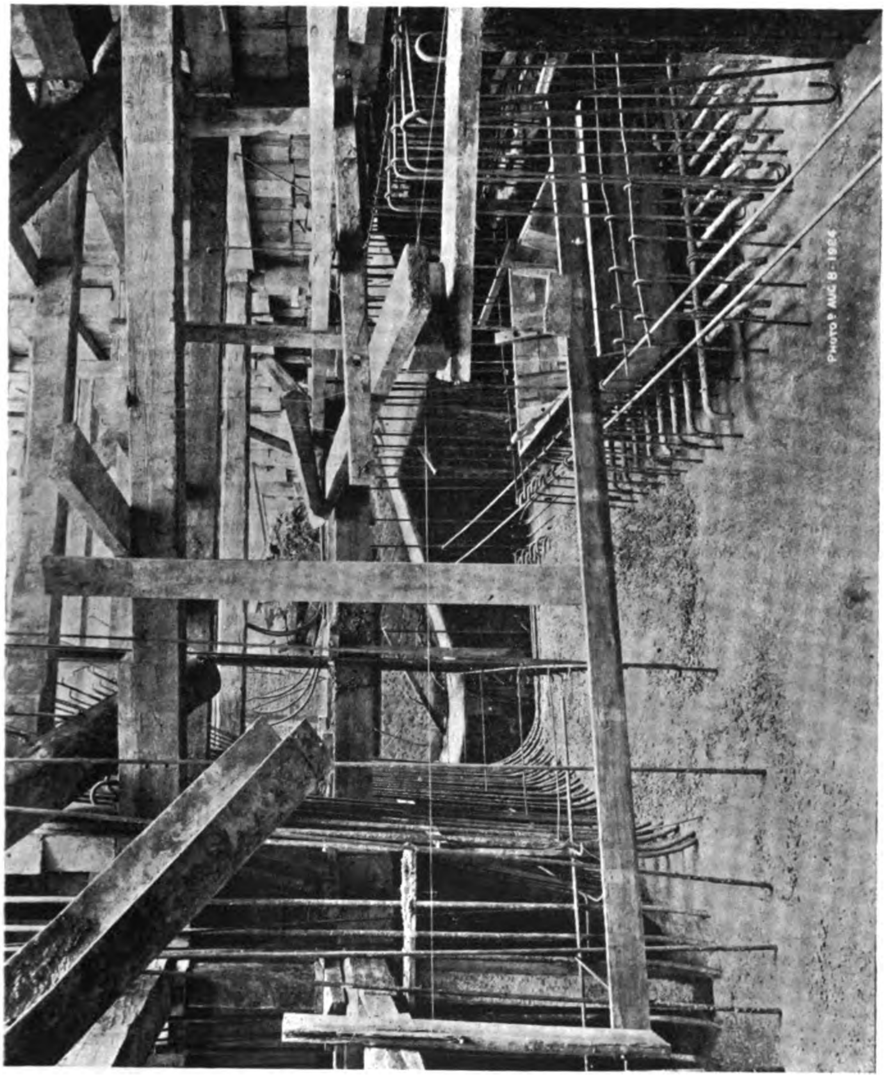


Fig. 4.—Reinforcement of Wall and Stanchion in Position.

REINFORCED CONCRETE SUBSTRUCTURE AT MESSRS. JOHN BARKER'S NEW BUILDING.

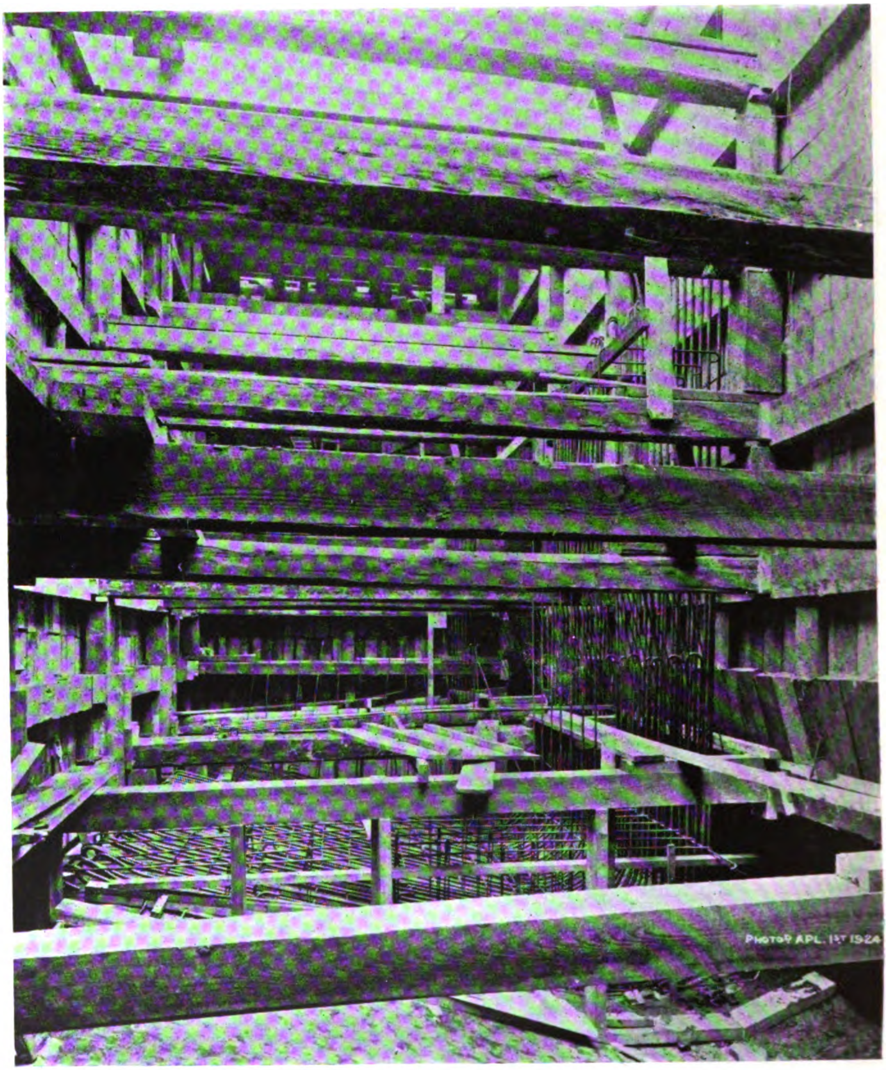


FIG. 5.—REINFORCEMENT OF WALL READY FOR CONCRETING.

REINFORCED CONCRETE SUBSTRUCTURE AT MESSRS. JOHN BARKER'S NEW BUILDING.

the quality of the strata at this level, whether the calculated head of water will even come up to the raft slab. Nevertheless, having regard to the importance of preventing any moisture whatever from entering the building, the raft has been designed against this contingency.

The reinforced concrete walls were constructed in trenches about 18 ft. wide, having a maximum depth of 35 ft. These trenches, as will be readily appreciated from their dimensions, required the most careful and efficient timbering. The walls, which are of a cantilever type, are 18 in. thick at the street level, increasing to 42 in. at sub-basement level, and are of constant cross-section.

As an indication of the general work necessary for the construction of the substructure of this building, it may be stated that 36,000 cubic yards of excavation is necessary.

Fig. 3 shows the asphalted surfaces ready for the reception of the reinforced concrete work, with an end view of a portion of the sloping base already concreted.

In *Fig.* 4 the reinforcement for a stanchion base and a portion of the wall is clearly shown. The shuttering to a stanchion base pit may also be seen in position. The surrounding concrete is being deposited.

Fig. 5 gives a view of the reinforcement for the lower part of the wall in position, ready for the concrete to be poured.

Messrs. P. and W. Anderson, Ltd, who are the contractors for the work, have taken every care with the concreting, and are to be congratulated upon the successful manner in which the work has been handled. When complete it will undoubtedly provide one of the best examples of the proper and economic use of reinforced concrete in the country.

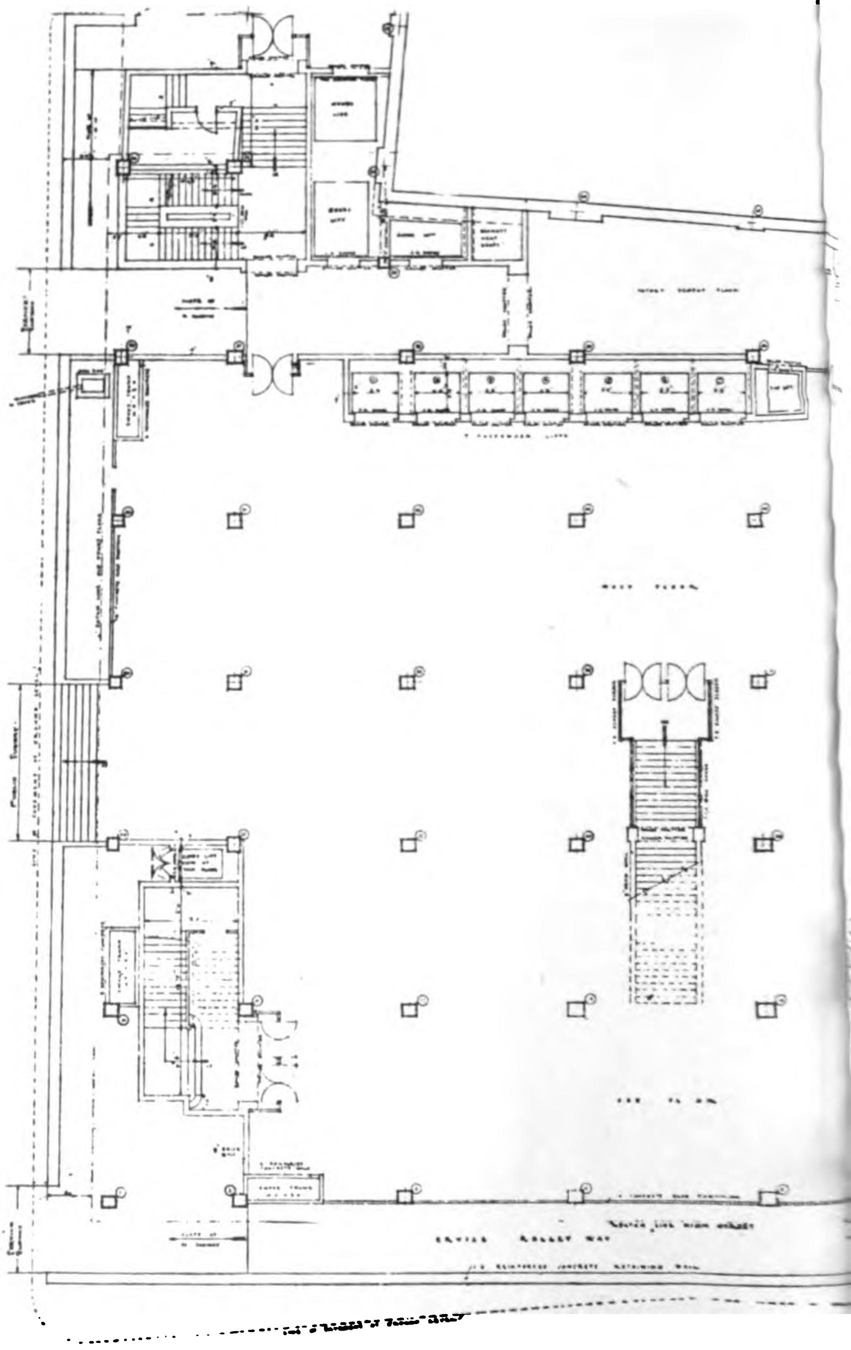
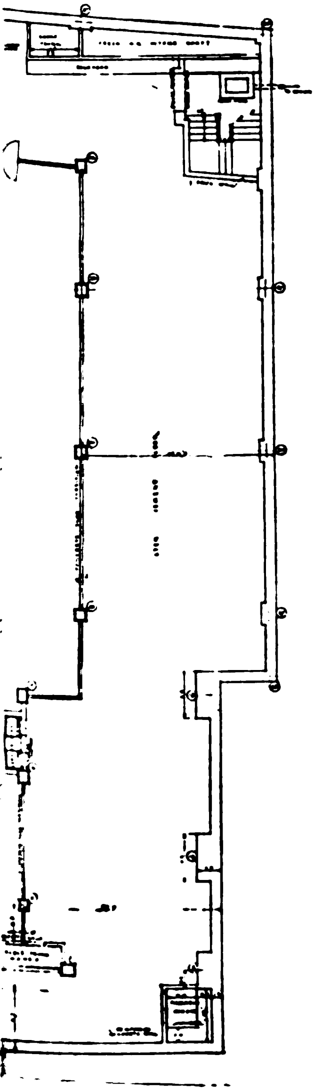


Fig. 2.—Plan at Basement Level.

REINFORCED CONCRETE SUBSTRUCTURE AT MESSRS. JOHN BARK



(See p. 575.)

HOW CEMENT HARDENS.

An explanation of the setting and hardening of Portland cement which differs considerably from those generally accepted, and indeed seems to disprove them, has recently been published by F. Tippmann, who disagrees with Kühl's theory that gypsum reduces the speed of setting by forming a calcium sulpho-aluminate with the tricalcium aluminate in the cement. He points out that the occurrence of this sulpho-aluminate in ordinary cement has never been proved, and that his own investigations suggest the production of colloidal matter simultaneously with crystals. He considers that the setting is not due to a saturated solution of lime, but to the dissociated sulphate-ion of calcium sulphate, as cements which are quite free from sulphates behave quite differently from ordinary Portland cement and do not swell in water, even after a year; yet when mixed with a small proportion of gypsum they swell to 200–300 times their original volume in 2 minutes. The addition of lime-water to sulphur-free cements has no effect, but free sulphuric acid acts like gypsum. In the absence of sulphate-ions, no colloidal gel is formed, but when the cement contains only 0·3 per cent. of gypsum abundant colloidal matter is produced by immersing the clinker in water. Gypsum was also found to inhibit the formation of crystals of calcium hydroxide. The author attributes the expansion and cracking of some cement-pats to an excess of gypsum, which decomposes the colloidal gel liberated by a very small proportion of gypsum. The effect of an increasing content of gypsum on the setting and hardening times of a cement is very striking, as the setting time remains almost constant, but the time of hardening increases with the proportion of gypsum, i.e. with the proportion of colloidal matter, up to a limit beyond which the gypsum begins to have a destructive action. In short, a little gypsum in cement restricts crystallisation and facilitates the formation of a colloidal gel. In other words, it is shown that a quick-setting cement owes this property to crystallisation from a supersaturated solution; a slow-setting cement to the much slower coagulation of a supersaturated highly dispersed colloidal sol. —*Zement.*

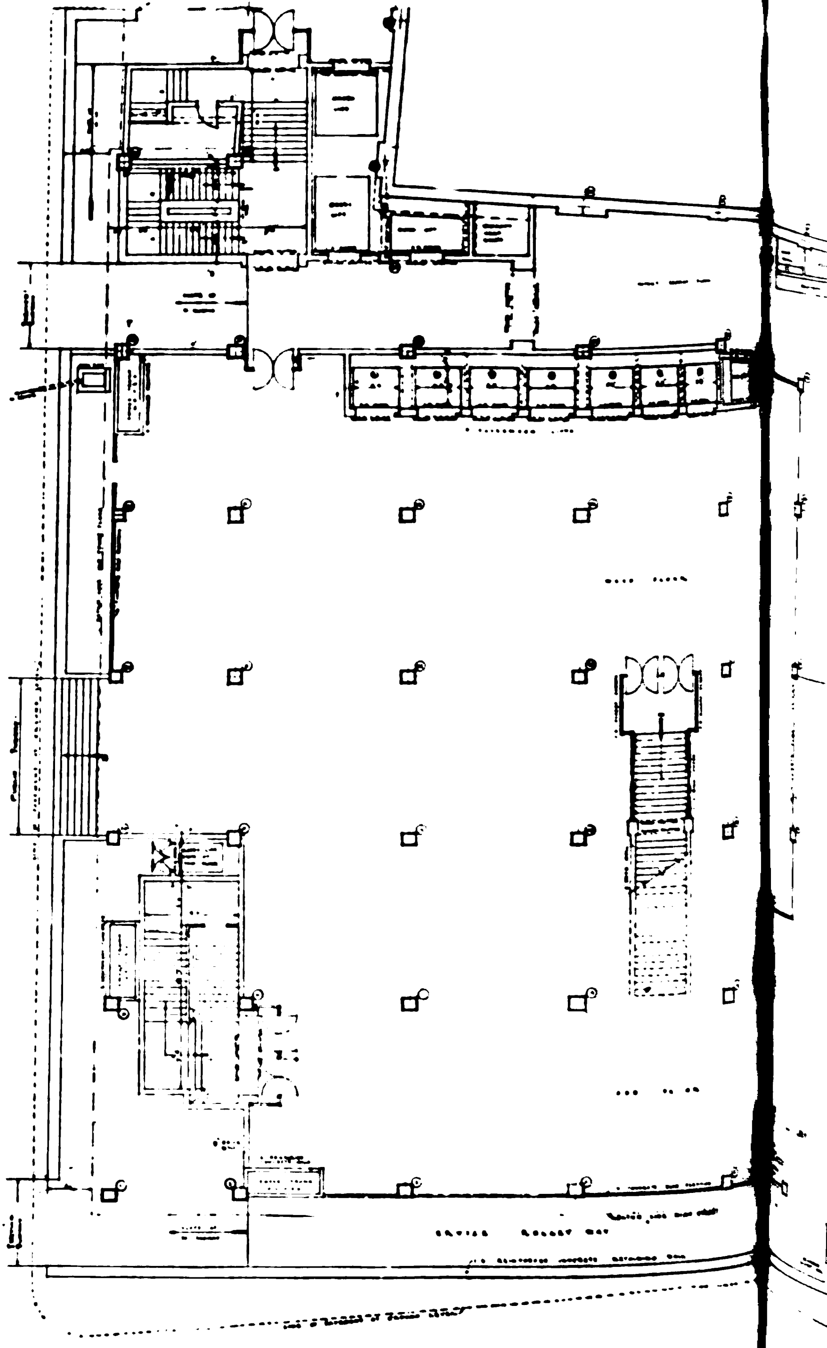


Fig. 2.—Plan at Basement Level.

REINFORCED CONCRETE SUBSTRUCTURE AT MESSRS. JOHN B

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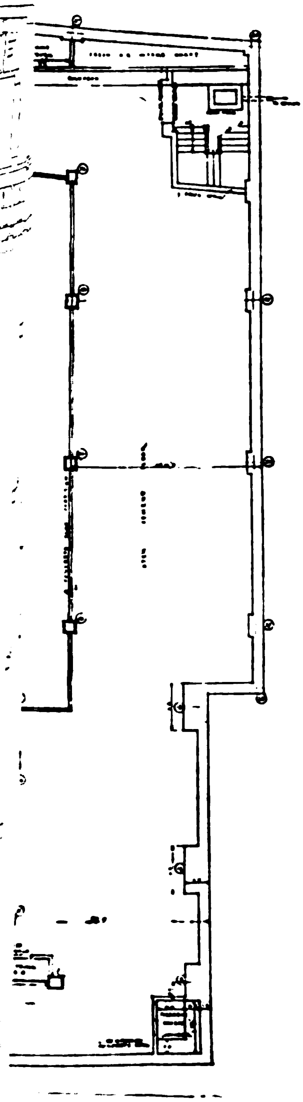


(*See p.* 575.)

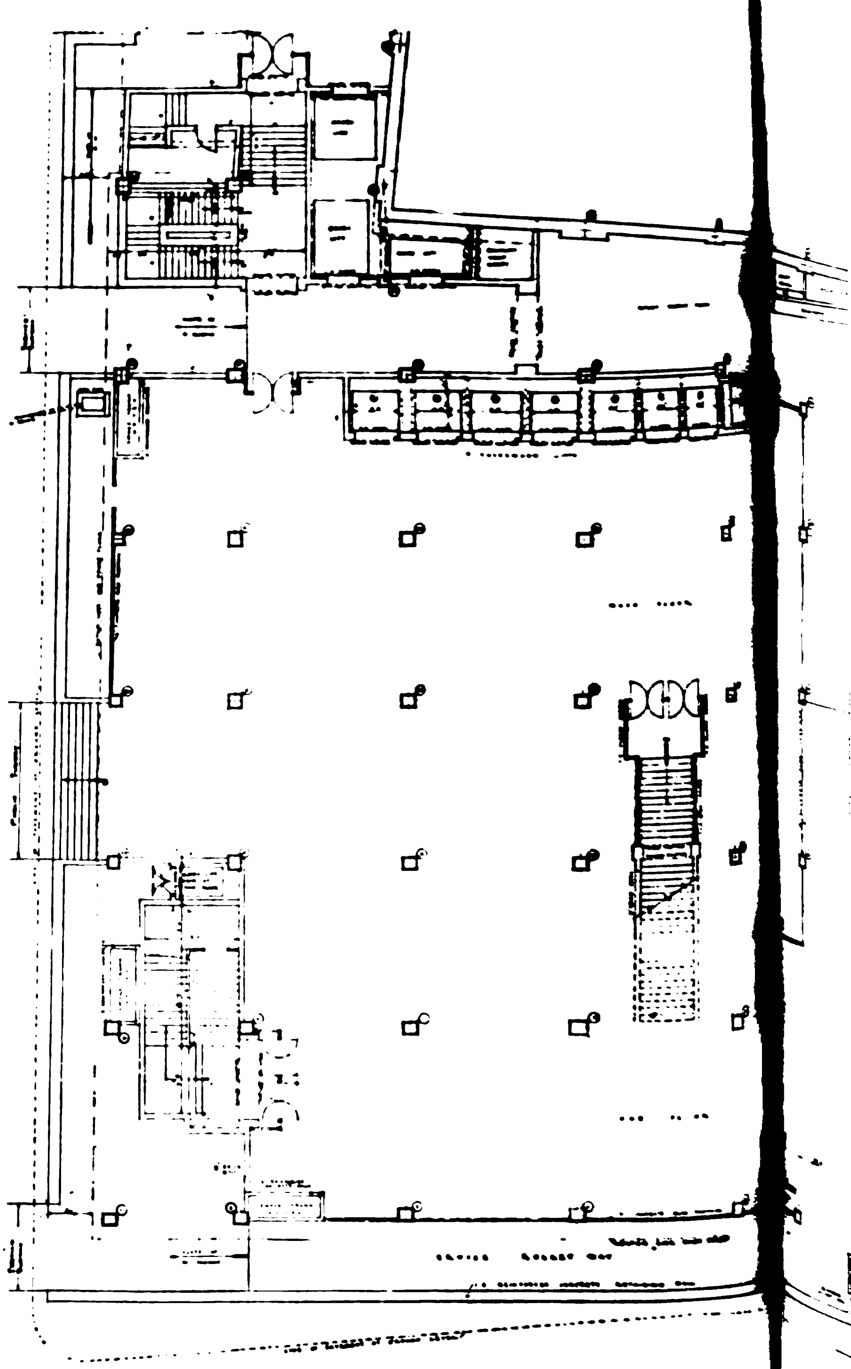
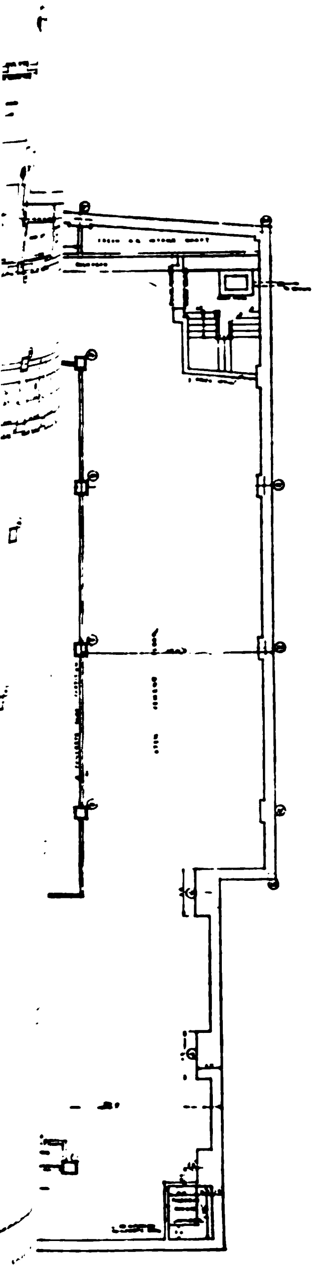


Fig. 2.—Plan at Basement Lev

REINFORCED CONCRETE SUBSTRUCTURE AT MESSRS. JOHN B



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BOOK REVIEW

"Einflüsse auf Beton." The chemical, mechanical and other actions on Concrete and Mortar of acids, alkalies, oils, vapours, water, soil, various stores, etc., and the precautionary measures against them. By Professor A. Kleinlogel.

Berlin: W. Ernst & Sohn. 331 pp. Price 20 frc. (Swiss).

THE author dedicates this book to the practical concrete engineer, and therefore endeavours to keep it as clear as possible from scientific complications. He has made an attempt to collect within one volume all the information on this subject, which hitherto has only been available in fragments.

It is a commonplace that in the construction of concrete or reinforced concrete structures the problems, the duties, and the care of the engineer are not at an end with the statistical calculations and technical details, but that it is most important to protect the concrete in after life as far as possible from any deleterious influences to which it may be subject by the use to which it is put, or by local conditions. Those engaged in the concrete world have long been alive to this fact, especially as it happens now and again that the circumstances in question lead to serious destruction of the concrete material. In most of the textbooks a short chapter, or perhaps only a few remarks, are devoted to this subject, while isolated tests and experiments carried out by private enterprise are not always published. This book should therefore be of great service to the practical engineer who cannot devote a great deal of time to looking up the fragmentary literature dealing with this matter. In order to facilitate still further the finding of any particular subject, whether cause or cure, the text matter in the book is arranged alphabetically like a dictionary, giving at a glance the essential facts in connection with any query, while the reader wishing to go further and obtain more exhaustive information in the matter is given references to all the latest literature dealing with the subject in question.

The author realises that he cannot claim to have collected in his book all the information on the matter that is worth having, the book being in fact a first attempt at collective treatment of a subject which has, up till now, mostly found expression in the "queries and replies" section of technical journals. The author has arranged the book in a somewhat unusual form, with alternate blank pages and spaces left between the various subject matters where the reader may jot down any supplementary information he may possess from his own experience on the problems in question; in this way it is hoped existing gaps may be filled and that the book may in time become a real help and valuable personal source of information.

For a book with such modest aspirations the subject must be said to have been treated most carefully and thoroughly, and the reader may obtain much valuable information on all the diseases that concrete is subject to, and the cures for them; he may learn, for instance, from three pages of interesting reading how an apparently innocent substance like peat may attack concrete, and the precautionary measures against the inroads from this source, or he may read all there is to know about the ravages of the cement bacillus.—R. N. S.

SLAG SAND AS AGGREGATE.

A LENGTHY investigation by H. Burchartz has, states *Stahl und Eisen*, shown that when slag is granulated or crushed so as to form a sand which will pass completely through a sieve with 20 apertures per inch it is quite satisfactory as a fine aggregate for both mass-concrete and reinforced concrete. As slag sand is more porous than natural sand a dense mixture (such as 1 : 2 : 3) must be used for reinforced concrete, in order to protect the reinforcement from rusting. Light slag sand produces concrete of slightly lower strength than that made with natural (quartzose) sand, but with dense slag-sand the strength of the concrete is at least equal to and is sometimes even stronger than that in which natural sand is used, because slag sand itself has cementitious properties. The setting and hardening of concrete made with slag sand are normal.

ECCENTRIC LOADS ON COLUMNS.

SIMPLE EXPERIMENTAL DETERMINATION OF POINT OF ZERO STRESS.

By T. H. FALLOWS, B.A.

THE usual method of finding the point of zero stress in eccentrically loaded columns of various sectional areas is somewhat heavy, involving long mathematical calculations or graphical methods for finding the radius of gyration of a section. The following gives a quick and reasonably accurate method of determining this experimentally, for the case where the load acts on an axis of symmetry of the section.

EXAMPLE.—Take the general case of a column of any section and let the load act on an axis of symmetry through the centre of gravity of the section.

Let G be the centre of gravity of the section.
„ R „ „ point of application of the load P.
„ h „ „ eccentricity in feet.
„ K „ „ radius of gyration of the sectional area about an axis through G perp. to RGR'.
„ A „ „ area of section (sq. feet).
„ g „ „ acceleration due to gravity $= 32{\cdot}2$ ft./sec.

If RGR' is an axis of symmetry.

The distribution of stress is given by the usual formula

$$p = \frac{P}{A}\left(1 + \frac{hy}{K^2}\right)$$

and is shown in *Fig.* 2.

The stress p vanishes when $y = \dfrac{-K^2}{h}$, i.e. at R' a point in continuation of RG at a distance $= \dfrac{K^2}{h}$ from G or $\left(\dfrac{K^2}{h} + h\right)$ from R.

Now take a thin section of the column (this may be a smaller model made of wood or any material whatever, since the mass cancels out). Suspend it about a horizontal axis through R perp. to RGR' and let it make small oscillations about xx'. (See *Fig.* 3.)

Note the time of a complete oscillation T secs. with a stopwatch.

Then the point of zero stress R' is at a depth

$$\left[g\left(\frac{T}{2\pi}\right)^2\right] \text{ ft. below } R \text{ (very nearly).}$$

PROOF.—Let $K_1 =$ the radius of gyration of the thin section about xx'.

When plane of section is at a small inclination θ to the vertical, and M is the mass of the section, the equation of motion is:

$$MK_1^2\,\frac{d^2\theta}{dt^2} = -\,Mgh\ sin\ \theta = -Mgh\ \theta$$

for small oscillations

$$\text{The periodic time } T = 2\pi\sqrt{\frac{K_1^2}{hg}}$$

$$= 2\pi\sqrt{\frac{K^2 + h^2}{hg}}$$

(very approximately if the thickness of the section is small and negligible in comparison with K or h)

$$\text{then } K_1^2 = K^2 + h^2 \text{ approx.}$$

$$\therefore\ g\left(\frac{T}{2\pi}\right)^2 = \left(\frac{K^2}{h} + h\right) = \text{distance from R.}$$

Q.E.D.

If a stopwatch is not available the experiment may be carried out by hanging on the axis xx', near to the plane section, a simple pendulum, i.e., a small weight on a very fine thread. Adjust the length l of this thread until the periods

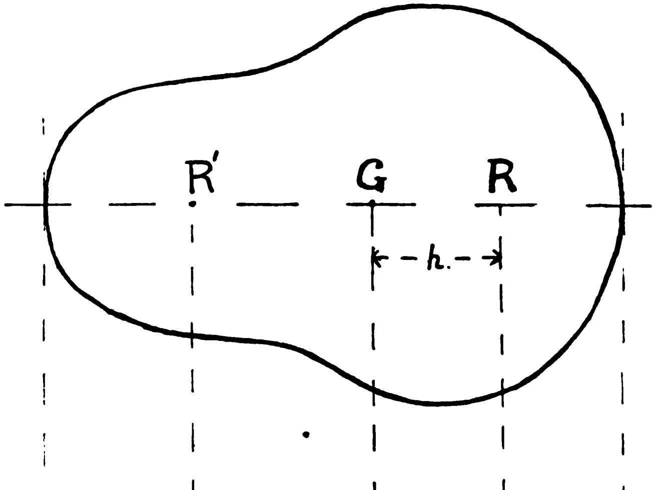


FIG I

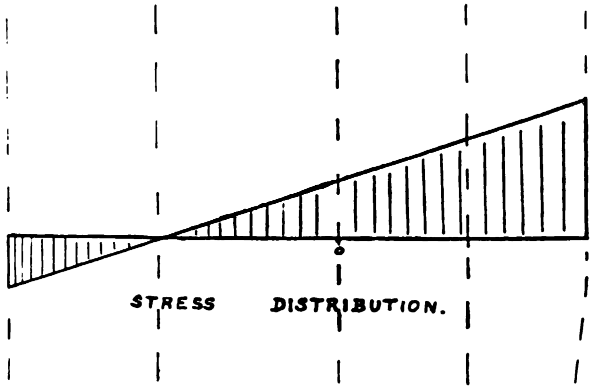


FIG II

of oscillation are the same. The length of this thread is the required distance RR'.

$$\text{for } T = 2\pi\sqrt{\frac{K_1^2}{hg}} = 2\pi\sqrt{\frac{l}{g}} \text{ for simple pendulum.}$$

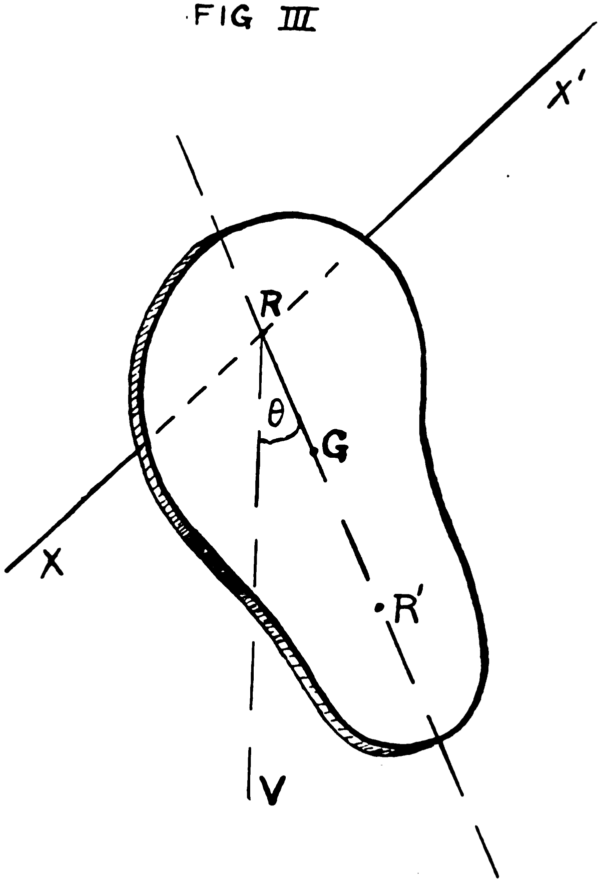
$$l = \frac{K_1^2}{h} = \frac{K^2}{h} + h \text{ (very nearly).}$$

The above formula

$$g\left(\frac{T}{2\pi}\right)^2 \text{ ft.} = \frac{12 \times 32\cdot2}{4 \times (3\cdot14)^2} T^2 \text{ inches.}$$

(9·8) T^2 inches is suitable for small sections where the air resistance is not too great to interfere seriously with the period of oscillation, and also with the important limitation that the thickness must be negligible compared with K or h. Also the load must act on an axis of symmetry through the centre of gravity of the section.

FIG III



EFFICIENCY IN ROAD CONSTRUCTION.

By J. H. WALKER, M.Inst.C.E.

Efficiency in roads is a relative term, and implies good economical roads capable of carrying the traffic imposed upon them with ease and comfort to both vehicles and foot-passengers travelling thereon.

In these days of heavy traffic with a speed up to 60 miles an hour (i.e. if we class big 60 h.p. touring cars as heavy), and of medium-fast and heavy traffic of 12 tons and over travelling at 15 to 25 miles per hour, the chief causes of road inefficiency are :—

(1) Corrugations and waving.

(2) Skidding—some roads under certain conditions being dangerous to motor cyclists and cars.

(3) Splashing of mud and oil on to buildings and also on to pedestrians on the footways.

(4) Uneconomical use of width of roadway due to slow traffic reasonably preferring the centre of the roadway to the sloping sides near the gutters. This results in danger to fast traffic as it has to swerve to the off side of the road to pass the slower vehicles. Such overtaking cars are then in the dangerous position of having to curve back to the centre of the road with perhaps excessive camber or banking in the wrong direction for such a proceeding. If the surface of the road be wet and slimy this often results in the back of the car taking control and skidding the car on to the kerb or grass margin.

(5) Retention of the cambered section of the roadway at curves making it dangerous to fast traffic.

The cause of (1) (i.e. corrugations and waving) is very simple, and arises from a combination of two sets of circumstances.

(*a*) Variations of contraction and expansion in the road crust due to diurnal and seasonal temperature changes and also to the crust being sometimes saturated with moisture. When hot or saturated with water the crust expands and when cold or dry it contracts. Water-bound macadam, when the crust is a few months old and consequently solid, having the interstices between the stones filled with grit, expands when saturated. But when saturated its compressive strength is much reduced. Any mud in the interstices of the stones is squeezed out into the surface, or the whole crust, unable to resist the compressive stress without lengthening, does so lengthen by folding into a series of arches in a similar manner to the way in which a piece of dry drawing paper pinned on to a board cockles up in waves when a wet sponge is passed over it. The cause of corrugation is lack of compressive strength, when the water-bound macadam crust is wet. Thirty years ago, there being no fast heavy traffic, the corrugations disappeared when the crust dried out. In newly-metalled roads this action does not take place until the crust is hard and solid. Before then, the interstices not being entirely filled, there is breathing room around each stone to take up locally the variations of expansion and contraction. Tar and bitumen-bound macadam, asphalte, etc., corrugate or wave for similar reasons. They expand for heat, and when hot lose their compressive strength, becoming more or less plastic. In this case also the road crust can only expand by rising upwards in a series of waves, the pitch and height of which are dependent upon the thickness of the crust. Thin crusts of 2-in. thickness on concrete have waves of less pitch and height than thick crusts. If heavy and fast traffic be absent when the road crust is in this particularly weak condition, the crust will resume its former position as the weather cools.

(*b*) Fast heavy traffic, acting upon certain unsuitable road crusts when they are under great longitudinal compression caused by their resistance to expansion stresses as stated under (*a*). In the case of water-bound macadam, a saturated crust which has just reached the age when it is hard and solid expands into a series of waves which can be clearly seen by a close observer when the early morning sun shines slantwise and longitudinally down such a saturated road, or when observed under the powerful head lamps of a motor-car. The action of numerous heavy and fast vehicles hammering the crown of these very flat arches shakes loose material from the interstices of the road metal into the space between the soffits of the arches and the formation. As the road crust dries out it contracts and the arches tend to disappear but in many cases are prevented from so doing by the presence of the loose material shaken on to the formation. When the road again becomes saturated, folding occurs to a greater and more irregular extent, and the action of the traffic is once more repeated, with added effect due to greater impact from the slightly uneven road. With every repetition of this saturation and drying out of a road crust the damage done by the traffic becomes greater until the corrugations are so bad that the road has to be hacked up and the vicious circle of repair, destruction, and hacking up repeated.

It is curious to note that in the early life of a road crust when the interstices therein are not entirely filled, thus giving breathing room, so to speak, between the stones, the corrugating action does not take place. Tar spraying, of course, acts as a preventative against saturation of the crust and it is reasonable to assume that it should be done as early in the life of a crust as possible, without waiting for the crust to become dense and solid. Against this, however, is the fact that the continual local expansion and contraction of the crust and of the superimposed tar-spray carpet will tend to make the latter lifeless and brittle.

Crusts of tar and bitumen and asphalte compounds suffer to varying extents from failure of compressive strength when hot, and consequently are more or less inefficient under fast heavy traffic, which crushes, pushes forward, or otherwise distorts the folds or waves caused by expansion.

Road crusts of wood-block paving or granite setts are favoured in regard to their greater ability to withstand corrugation from the fact that not only are they laid with numerous joints filled with plastic material or otherwise, but they have the essential quality for efficiency as material for a road crust in that they have great compressive strength when hot or wet.

If it be granted that the above statements are correct, we arrive at a most important conclusion, which is :—A road to be efficient to withstand the damaging effect of fast heavy traffic must of necessity be made with a crust having great compressive strength when either hot, cold, dry, or wet.

In considering the choice of a material for road construction which will have the above characteristics, we must bear in mind the use on nearly all our roads of fast heavy vehicles, which traffic will increase in speed and weight as time goes on. This will necessitate in the near future a radical reconstruction of our road systems if the cost of maintenance of roads and vehicles is to be kept within reasonable limits.

It is necessary therefore that such material shall be economical in first cost and involve small maintenance charges. The only material which answers all the above requirements is concrete, enormously strong in compression in all conditions to be met with in road usage, but often requiring reinforcing to give it the tensile strength it lacks. Many engineers have recognised the great advantages of constructing roads in concrete and such roads have and are being made in large numbers. For want of co-ordination, engineers here and there are laying down experimental stretches of road and by repeating the mistakes of earlier experimenters are liable to pay more for their experience than should be necessary. Concrete roads properly constructed with expert knowledge, perhaps dearly come by, should be as nearly perfection as possible ; not properly constructed to carry fast heavy traffic they will be more or less a disappointment to those responsible for their construction.

For the guidance of others, the writer gives a few of the essentials he has found necessary or advisable :—

(1) The concrete must be of sufficient thickness and strength to stand longitudinal compressive stresses caused by expansion due to a hot summer temperature. If the design is incorrect, the crust may arch or fail by buckling with one section over-riding the adjacent one. It requires little knowledge of reinforced concrete and of the effects of temperature thereon to calculate that, with a slab wherein the concrete is laid in the continuous method—compression stresses will be induced in the concrete on a hot summer's day of such large amounts as 60 to 70 tons per sq. ft. and over. Such stresses readily account for the arching and buckling of thin and badly-designed concrete crusts which, moreover, have to carry fast heavy vehicles when thus already overstressed by temperature variations.

(2) The concrete must be laid in alter-

nate bays and the intervening bays filled in later.

(3) Each bay must be interlocked with its neighbour.

(4) If the formation be cambered, more reinforcing steel must be provided transversely of the road as well as longitudinally therewith.

(5) Concrete contracts equally in all directions, therefore ample steel reinforcement must be provided in two directions at right angles to one another. Where the formation is of a doubtful character, either as a whole or in patches, the road must be adequately reinforced.

(6) The surface concrete should contain large granite aggregate, the larger the better, e.g. to pass through a 2½-in. ring and be retained on one of 1½-in. diameter. This will give foothold for horses, prevent skidding and give a hold to a tar carpet if the road is to be surfaced.

(7) The surface should be washed and broomed free of laitance about 24 hours after the initial set takes place. The aggregate of the surface layer, being large and deeply bedded in the matrix, will not be loosened or disturbed by such brooming.

(8) A wearing surface of tar sprinkled with granite chippings should be applied every 1, 2 or 3 years, according to amount of traffic. This coat should be as thin as possible and will span the minute joints between adjacent bays. If the concrete be covered with a thick carpet of material having no compressive strength when hot, such carpet must inevitably fail by waving or corrugations.

THE INVENTOR OF PORTLAND CEMENT.

In commemoration of the centenary of the invention of Portland cement by Joseph Aspdin in 1824, a bronze tablet was unveiled at the Town Hall of Leeds, Aspdin's native town, on September 6. The tablet is 5 ft. 6 in. by 3 ft. 6 in., and bears an inscription in the following terms : " In memory of Joseph Aspdin, of Leeds, stonemason, 1779–1855, whose invention of Portland cement, patented October 21, 1824, followed by a century of improvement in its manufacture and use, has made the whole world his debtor. This tablet was presented by the American Portland Cement Association on the occasion of the united celebration with the British Cement Makers' Federation of the centennial of the invention, October, 1924." Members of the British Cement Makers' Federation and the American Portland Cement Association were present at the unveiling ceremony, which was performed by the Lord Mayor of Leeds, Sir William Airey, who, appropriately, is a prominent builder carrying out a large number of concrete housing schemes.

CORRESPONDENCE.

PROPORTIONING CONCRETE.

Sir, — The abstract of Sir Owen Williams' paper in your July issue, on concrete at Wembley, etc., is fortunately read chiefly by those whose interest includes your journal, and who probably can sift the cement from the aggregate in arriving at a concrete conclusion.

With all due respect to Sir Owen, whose concrete creations may serve to enhance both his and concrete's reputations, I am bound to state that his opportunity of being lavish with cement, as expounded in his article, will not assist concrete to its rightful place in construction, except for edifices wherein economy is no consideration.

To one with twenty years' practical experience, in both hemispheres and extremes of climate, in the design of, planning for, and manufacture of concrete on a commercial basis, the idea of a 1–1½–2 mix is absurd. One does not need to stick cement to cement, for if care be taken to fill the sand voids with cement and the stone voids with the sand mix, enough of each will suffice to make an impervious concrete, subject of course to water and mixing—unless, as I have found, some cements are conductive of moisture, when the more used the worse the result. Water will not percolate through the actual particles of sand or stone.

A 40 per cent. sand void with a 45 per cent. aggregate void is a wide margin, and a 50 per cent. cement to sand and sand to aggregate, i.e. 1–2–4, accomplishes the desired end. A 30 per cent. sand void and a 35 per cent. aggregate void, readily obtained (1–3–6 mix), make a good concrete, but in all cases the mixing is more important than the mix. I have made a 1–3–12 concrete with less than a 1 per cent. absorbency, and over 3,000 lbs. per sq. in. compression resistance, but this was a laboratory experiment not commercially possible, yet showing what care can do.

For habitable construction a concrete should not be absolutely impermeable, and is easily made less absorptive than a good brick from a 1–2½–5 mix, with a more than comparable compressive strength.

The American propaganda for 1–3–6 concrete block work shows a Pullman car balanced upon a single hollow block 18 in. by 8 in., bearing area being 96 sq. in.

For reinforced construction absolute imperviousness is necessary, and without fillers this should be accomplished with a 1–2–4. (It being understood that the figures are approximate; for instance, a 1–2–4 may mean anything within margins of 10 per cent. both ways.)

Sir Owen is to be congratulated upon the effective use of his opportunities, which the cognoscenti of concrete probably appreciate more than most.

Charles Marques,
Managing Director,
Concrete Manufacturers (No. 1 London), Ltd.

We have submitted the above letter to Sir E. Owen Williams, who replies as follows:—

"Sir,—Mr. Charles Marques appears to miss my principal argument in favour of concretes rich in cement, viz., that its use is not accompanied by in-economy but often in fact by actual saving in cost.

"A cubic yard of 2 : 1 : 1 concrete and of 4 : 2 : 1 concrete contains 860 lbs. and 510 lbs. of cement respectively. The difference of 350 lbs. costs, at £3 per ton of cement, approximately 9*s*.

"A cubic yard of 4 : 2 : 1 concrete, exclusive of centering and reinforcement, costs approximately 50*s*., and therefore on the same basis 2 : 1 : 1 concrete would cost approximately 59*s*. per yard cube, i.e. 18 per cent. more.

"A 2 : 1 : 1 concrete is 60 per cent. stronger in all respects than 4 : 2 : 1 concrete, and hence a smaller yardage may be used, which will more than offset the additional unit cost of the better material.

"I endeavoured to emphasise sufficiently in the paper referred to the other advantages of the better material. Only by its adoption can we be saved the much more serious in-economy due to the rapid deterioration of marine and other structures of concrete containing the barest minimum of cement, which unfortunately is to-day being witnessed throughout the world.

"Even if the design of a structure in 4 : 2 : 1 concrete were not altered one iota, except changing the mixture to 2 : 1 : 1 concrete, the increase in cost on the whole work would only be about 5 per cent., which would not be too much to pay for permanence. Actually, by taking advantage of the better qualities of the better material, permanence is achieved at equal, if not less, cost."

TESTS ON CONCRETE FLOORS AND COLUMNS.

Some idea of the vast amount of useful research work now being carried out by the National Physical Laboratory may be obtained from the Report of the Laboratory for the year 1923, just published by H.M. Stationery Office, price 13*s*. 6*d*. net.

Of particular interest to readers of this journal is the brief account of tests on concrete columns and floors carried out by Mr. J. H. Hyde, A.M.Inst. C.E., A.M.I.Mech. E.

In the tests on columns, two plain steel and two steel-concrete columns, 20 ft. long, have been tested, in the concrete building, on compound knife-edge pivots. The steel in each case consisted of joists 5 in. by 1½ in., fitted with end plates screwed to the joists by cleats. The steel and concrete columns were encased with concrete to outside dimensions of 8 in. by 7½ in. The buckling load of the steel columns was identical with that estimated by Euler's theory and was 12·72 tons, and the corresponding load for the steel-concrete columns was 46·1 and 40·4 tons respectively.

A series of floor slabs of the following dimensions were tested on a 14-ft. span :

(i) Steel frame consisting of two steel joists, 6 in. by 3 in.

(ii) Steel-concrete floor consisting of a frame of four steel joists (6 in. by 3 in.), spaced 22 in. apart and encased in concrete, the concrete being flush with the steel, both at the top and bottom of the slab.

(iii) Steel-concrete floor, consisting of a frame of four steel joists (6 in. by 3 in.), spaced 22 in. apart and encased in concrete, the concrete being flush with the steel on the tension side and standing 2 in. beyond the steel on the compression side, making the slab 8 in. thick.

(iv) Steel-concrete floor, similar to (iii), but with three joists instead of four.

(v) Steel-concrete floor similar to (iii), but with 4 in. of concrete on the compression side of the steel, making the floor 10 in. deep over all.

The load was applied across the width of the floor at the third points of the span.

Special apparatus designed and made in the Department was employed to determine the deflection of the specimens at several points along the span, the measurement being independent of the yielding of either the supports at the ends or of the packing between the slab and the supports. The deflections made were measured to within 0·0005 in.

The slabs were inverted in the testing machine and the load applied from the underside, thus leaving the upper or tension side exposed for examination. This latter surface was coated with "Duresco" paint (dead white), and this served to show up the cracks in the surface as they developed. These cracks were marked in carbon, labelled with the load at which they occurred, and the slab was finally photographed to obtain a record of the test.

In these tests a determination was made of the actual extension of the steel and the compression of the concrete at the exposed surfaces, which showed that the failure in each case occurred due to the yielding of the steel.

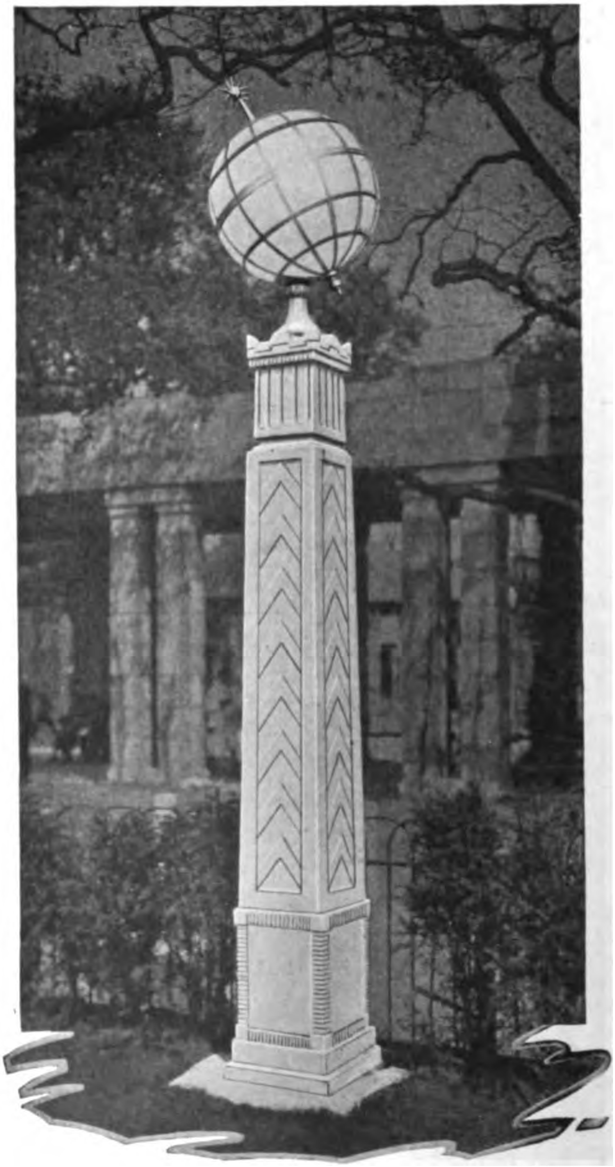
CONCRETE PRODUCTS.

CONCRETE PRODUCTS AT WEMBLEY.

THE British Empire Exhibition is a city of concrete. The whole place is, in fact, a "product" of concrete, but apart from the uses of the material in the constructional work of the buildings, which were dealt with in our July issue, the application of concrete to smaller uses is to be seen at every turn. From these there is much to be learned by all interested in concrete, and by everybody visiting the Exhibition if they were alive to the possibilities of the material in their everyday life. In the home, and especially in the garden, there are practically unlimited opportunities for using concrete and thereby obtaining an article better in all respects than a similar article at present generally made of other materials — garden posts, frames, store sheds, tennis posts, rollers, etc., which are everlasting and never require painting, which increase in strength with age and gain in appearance with exposure to the weather; garden edging which never rots or crumbles away in unsightly pieces; vases and sundials, garden ornaments of all kinds, which by the use of coloured cements or the addition of a colouring material can be had in any desired colour or shade; and a host of other outdoor things which are a continual source of trouble and expense to keep in order or to renew when made of wood are made in concrete and need no attention or additional expenditure after they are first installed. And, moreover, the initial cost is not a great deal more than that of good timber, and much less than natural stone. There can be no doubt that the opportunity over ten million people have already had of seeing what is now being done in concrete will create a considerably greater demand for these goods.

A CONCRETE GARDEN VASE.
(MADE BY SANDERS & CO, LONDON.)

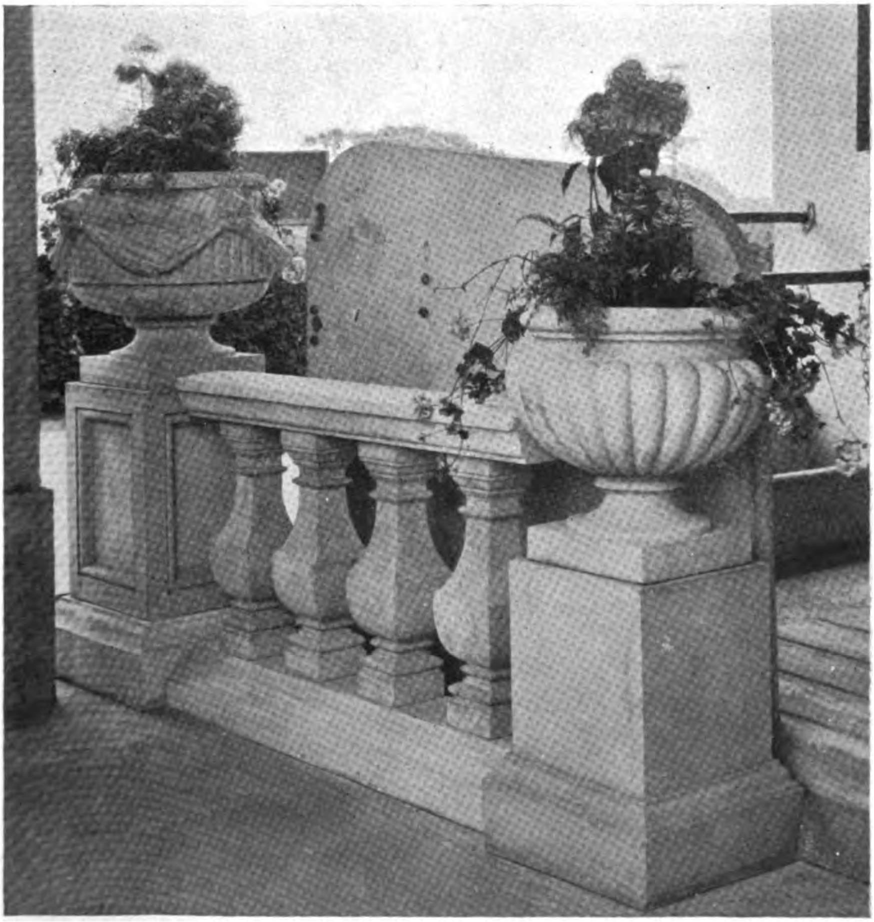
The thin slabs, formed of a breeze backing and a facing about 1-in. thick of a cement sand mix in which a slight amount of colouring material was incorporated, with which parts of some of the buildings are faced, are seen to be weathering well after several months of exposure, and are now assuming a pleasant mellowness. They are beginning to reply to the critics who when the Exhibition was first opened pointed to what they called the stark appearance of the wall-surfaces, forgetting that time can be as kind to concrete as to any other building material.



CONCRETE LAMP-POST AT WEMBLEY.

The first of the smaller applications of concrete to meet the eye are, of course, the lamp-posts, of which there seem to be thousands. Our illustration shows that these have been well-designed for their purpose, and that their gracefulness has not entailed much expense for elaborate moulds. While concrete, like any other plastic material, can be moulded to any fantastic shape, it will, we think, always be found that simple lines give the best effects. A study of these posts shows that they were made simply by inserting in the mould a few blocking pieces and strips to form the frets and the chevrons, an inexpensive process which has produced a result quite as pleasing as if a more elaborate design had been attempted. It is probable that, where something other than a flat wall surface is required, a much better effect would be obtained by a ribbed surface than by many of the imitation-rock face blocks so often seen, for while the faces of blocks of natural stone are never cut exactly alike, "rock-face" concrete blocks set side by side and one above the other are as like as peas in a pod, and lose in interest because of their similarity unless a number of different pattern moulds are used or a varied surface obtained by the use of colouring.

The drinking fountains have been designed with the same object in view,



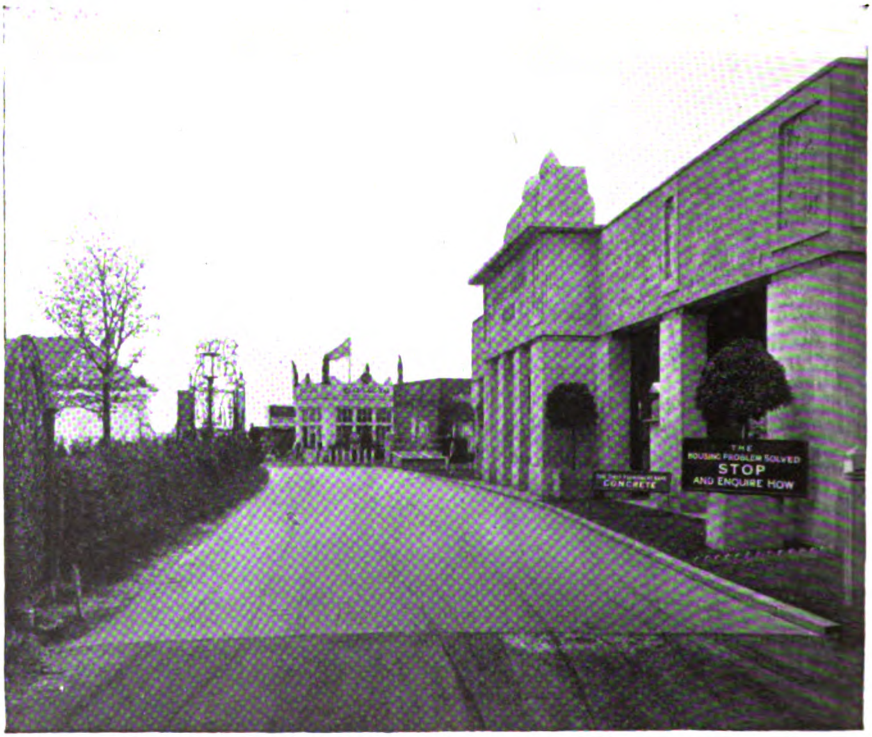
CONCRETE BALUSTRADE AND VASES.
(MADE BY THE LINDUM STONE CO., LINCOLN.)

that is, the strength and solidity of concrete expressed in the shape and relief obtained by incised decoration rather than protuberances. The lion, the symbol of Wembley, is reproduced in concrete on the fountains, and similar concrete lions' heads are to be seen in large numbers forming bases for the many flagstaffs made of the same material which enliven each side of the main avenue.

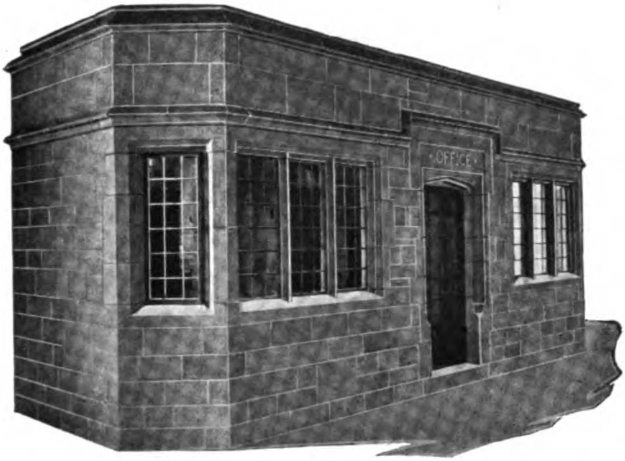
On the more brightly-coloured stands and kiosks the colour wash on the concrete is wearing well, but would probably have to be renewed each year if the Exhibition is kept open. For permanent buildings on which a coloured surface is required it would no doubt be cheaper to use a coloured cement or to incorporate a colouring material when mixing the concrete so that the walls would be coloured throughout and not be subjected to the danger of patches being washed or worn off.

The bulk of the concrete products are in the Horticultural Section, and here they are chiefly to be seen on the stand of the Concrete Utilities Bureau. In making his way to this section one is liable to receive a rude shock in passing the Burma Pavilion, for here is a massive-looking balustrade, which from a distance has every appearance of concrete, bearing a notice: "Fragile: Do not lean on the balustrade!" And the warning is not unnecessary, for it shows signs of serious wear; large pieces have been broken away, exposing more clearly the plaster of which it is made. No doubt the authorities are already regretting their choice of material for the balustrade when none of the concrete in the Exhibition shows any signs of deterioration.

It is in the Horticultural Section that the best piece of road in the Exhibition is to be found. In many parts the traffic is playing havoc with the water-bound macadam and tarred roads, which have been very trying in wet weather, but the section of concrete road laid down by the Concrete Utilities Bureau in front



CONCRETE ROAD AT WEMBLEY.
SHOWING JUNCTION OF CONCRETE AND MACADAM SURFACES AFTER RAIN.



BUILT OF CONCRETE SLABS WITH SURFACE OF CRUSHED HAM STONE CONCRETE.
(Office of the Concrete Utilities Bureau.)

of its stand is as smooth as when laid, and, further, the surface rapidly dries after rain. An idea of the cleanness of the concrete road compared with the other roads may be gathered from the photograph given in this issue, which shows the junction of the two types of surface after a shower. It is interesting to note that 1,000 tons of traffic went over this section on the eleventh day after the concrete was placed.

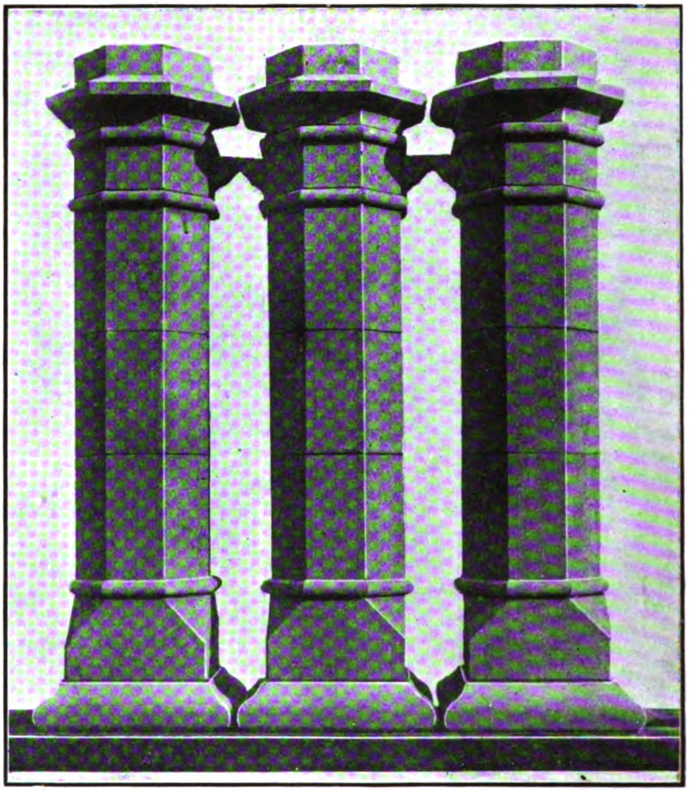
The front of the stand, which is of concrete, was illustrated and described in our July issue. Inside, the part walled off to form an office is also of interest, as by the use of crushed Ham stone and a little colouring material the slabs of which it is formed have every resemblance of that stone. The slabs have a backing of gravel concrete and a surface of the reconstructed stone. After they had matured they were tooled as a natural stone would be tooled, with the result that the irregularities form a much more pleasant surface than if they were left as they came from the mould. A variety of surface treatments is demonstrated by panels showing in a practical manner not only how concrete may be made beautiful but also how, owing to the infinite range of shades which are possible by the use of coloured cements and blending different coloured aggregates, it has possibilities for artistic decoration far beyond those of any other building material with perhaps the exception of marble. Panels of roughcast and pebble-dash are shown, and a series in which the aggregate has been exposed by scrubbing the film of cement from the surface. The latter range from black to white, the aggregate mostly being chippings of coloured marble, granite or other stone, and coloured sand, and the variety of effects to be obtained from the use of coloured cements is also to be seen.

On the stand a large number of exhibits lent by different manufacturers are shown, many of which are already fairly well-known but some of which are exhibited here for the first time.

Some concrete crazy paving shows how much easier it is to lay than the usual method of fitting together random stones and at the same time get the effect of no two stones being alike. In the specimen exhibited the paving is supplied in twelve different shapes which fit together like a jig-saw puzzle, the set of twelve making about 4 sq. ft. of paving. If the path is 2 ft. wide the pattern is thus repeated every 2 ft. along its length, but owing to the random sizes of the different pieces this cannot be detected except on very close inspection. The pieces of paving are made in light strip-iron moulds.

A garden-seat has end pieces of reinforced concrete and a seat formed of wood slats. The slats are passed through holes in the end pieces and fastened with wedges, so that it is an easy matter to dismantle or erect the seat.

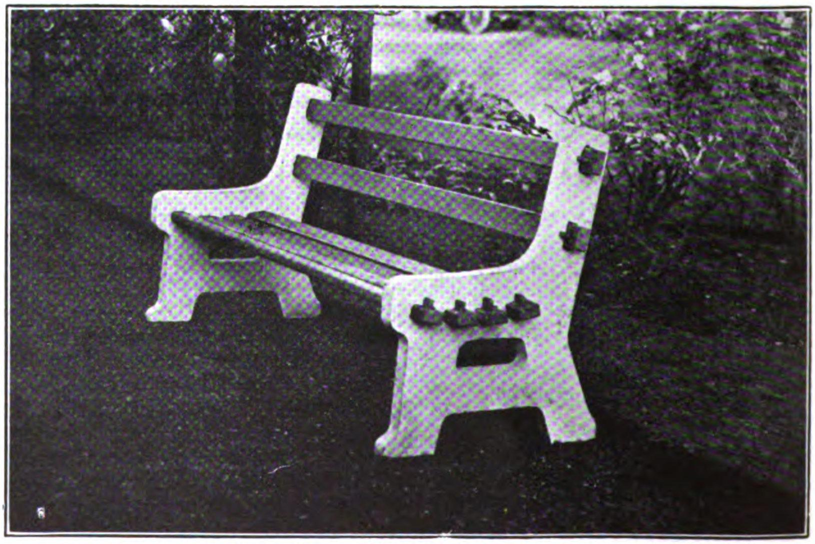
A neat method of surface drainage for roads, and one which avoids the use of iron



[*Mr. C. W. Pike, A.R.I.B.A., Architect.*

CONCRETE CHIMNEYS AT "THE HYDE," BRIDPORT.

(MADE BY WHARF LANE CONCRETE CO., LTD., ILMINSTER.)



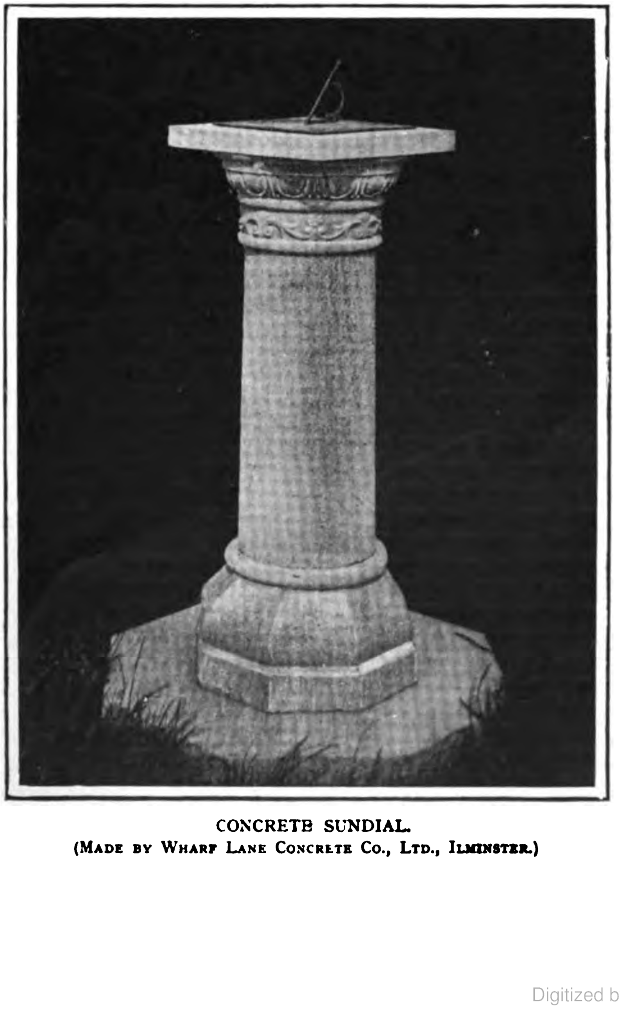
GARDEN SEAT WITH CONCRETE ENDS.

(MADE BY MANUFACTURED CONCRETE WORKS, LONDON.)

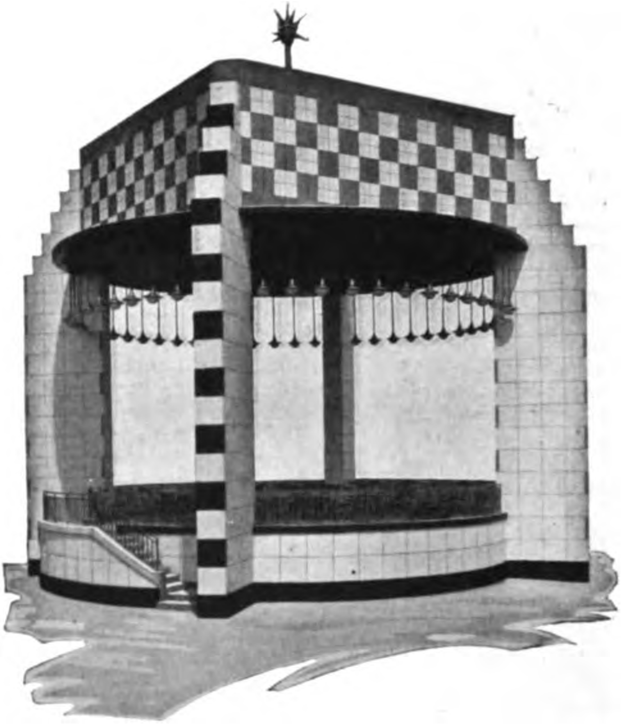
gratings in the gutters, has the catchpit placed under the footpath near the kerb, and the water drains into it through channels cast in the vertical face of the kerb. The catchpit, kerb and cover are made of pre-cast concrete units. This type of catchpit is, of course, only suitable for level roads, as on a hillside the water would run down the gutter and pass the entrances to the catchpit.

Among a large selection of concrete posts for different purposes are to be noticed some types of tennis posts in which the necessary winding apparatus and pulley are fixed. Posts for grass courts are made with a foot so that they will stand firm without being embedded in the ground, a small hole being left in the toe through which a piece of iron can be driven into the ground, which, with two screwed pegs in the heel, keeps the post in position. A hollow telegraph pole formed of sections about 4 ft. high, contains six longitudinal holes through which steel bars are threaded and grouted in after assembling. Pit props for permanent roads in mines have cross-beams to support the roof fixed by a ball and socket joint to the tops of the posts.

A cold-frame made in sections so that it can be extended when necessary, and fitted with wooden glazing bars ; concrete window frames ; sundials and garden vases with well-defined ornament ; sewer tubes ; manholes ; an economical type of penstock ; reinforced concrete railway sleepers ; a rick stand formed of pre-cast units fitted together with lap joints and supported on posts which curve outwards at the top to prevent vermin from reaching the rick ; tiles in various colours and patterns ; reinforced concrete safes and strong-room doors ; various products in asbestos cement ; a garden roller which



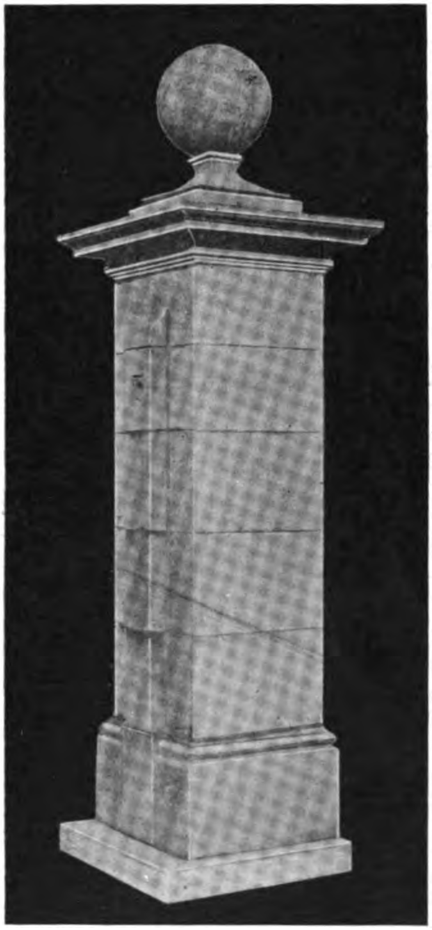
CONCRETE SUNDIAL.
(MADE BY WHARF LANE CONCRETE CO., LTD., ILMINSTER.)



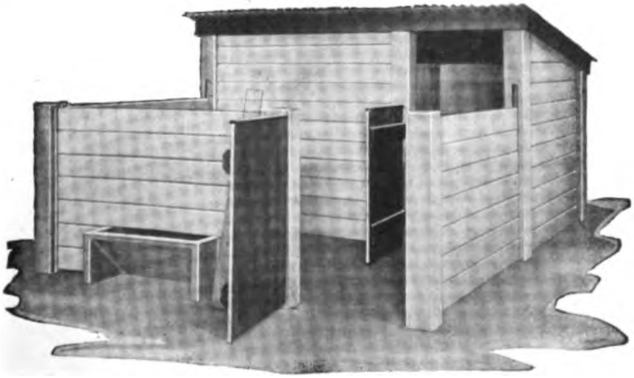
CONCRETE BANDSTAND WITH PAINTED SURFACE.

may be filled with water to increase its weight; sections of concrete-block walling; flower boxes moulded with a representation of sculpture on the sides; a pergola with a texture similar to Portland stone; a hygienic pig-stye in which the members are fitted together by tongue-and-groove joints and can thus be rapidly taken down and re-erected and in which the slabs and posts are standardized so that the minimum number of moulds are necessary; an all-concrete and asbestos-cement poultry house; cowstalls; silos; an ecclesiastical window; and a host of other products of concrete go to make an exhibition which should interest not only the agriculturist and estate owners, but everyone who possesses even the smallest patch which could be "furnished" more cheaply and more lastingly by the use of concrete articles.

A casual glance at the concrete and cast-stone products at the Exhibition shows the enormous strides which have been made in recent years both in the improved quality and the extension of the uses of concrete for small articles. Some of the most important buildings in the country are now faced with cast-stone, and the number of concrete door-hoods, window frames, fountains, vases, lamp-posts, direction posts, etc., turned out each year must be very considerable. Many of these moulded articles, to be seen at Wembley and elsewhere, are admirably designed and pleasant to look at, which is at it should be, for the crude designs and workmanship which characterised some of the early productions of this industry undoubtedly brought concrete into disrepute with those architects who were not fully aware of the possibilities of the material. Decoration or intricate castings in concrete are essentially subjects for mass production. If costs are to be kept down to a level which will compete with cut stone a large number of articles must be made from one mould, and it is therefore more than ever desirable that that mould should be made from the best design obtainable. If manufacturers have not a competent artist on their staff it would probably in every case be a good investment to obtain expert advice on the question of design, or to consult an architect with a knowledge of the possibilities and limitations of the material. The extra cost, spread over a large output, would be practically negligible; certainly it would benefit the individual manufacturer and the industry as a whole in preventing unlimited numbers of articles being cast from a mould which could have been improved by that little attention to detail which makes no more trouble in the first place but means all the difference between a commonplace production and one which appeals to the eye and to the sense of the fitness of things as do all beautiful things, be they of concrete or any other material. We say this in no spirit of criticism of the established firms who are doing so much to keep up and improve the standard of their productions. But the industry is now in its infancy compared with what we are convinced is possible in the future, and it will be all to the good if those engaged in the manufacture of concrete products of a decorative nature bear in mind that other industries which can be likened to it, such as pottery, have found it a paying proposition to employ artists to prepare their designs. We all know articles of everyday use, or which we continually see in the home and the streets, that could just as easily have been made in more pleasing shapes or with less obtrusive colour at no more cost, but which we have to bear with because no others are generally available. Let us keep concrete beautiful as well as useful and enduring when intended for adornment, and as simple and unobtrusive as possible when it is for utility only.



CONCRETE GATE POST.
(MADE BY WHARF LANE CONCRETE CO., LTD., ILMINSTER.



CONCRETE SECTIONAL PIG-STYE.
(MADE BY TEIGN VALLEY GRANITE CO., LTD., CHUDLEIGH.)

CEMENT RESEARCH.

In persuance of its objects of reducing the cost and improving the quality of cement, the British Portland Cement Research Association is investigating the subject of grinding. In the manufacture of cement, the power required for grinding not only the finished cement but the raw materials and the coal used for combustion amounts to more than 50 electrical units per ton of cement, while the quality of the cement is directly connected with the degree of fineness of grinding. Hence the subject is one of importance.

At the outset of the investigation it was realised when seeking to formulate the relation between the power expended in grinding and the result produced that the ordinary sieve tests were useless for expressing the real fineness of grinding. Two powders may be identical so far as sieve tests are concerned, but sieve tests do not reveal the fineness of grinding of the particles passing the sieve. Another standard of fineness had therefore to be established, and the number of particles and their total surface was ultimately adopted as the basis.

In their pamphlet No. 4, entitled "Researches on the Theory of Fine Grinding," the Research Association has published the preliminary results of the investigation, and although the practical stage has not been reached an important theoretical law governing the rate of increase in the number of particles produced by crushing has been discovered which will doubtless be the basis of further work leading to practical advantage. The immediate object of the research is to determine what proportion of the power expended in grinding is employed in doing the essential work of breaking up the particles. When this information is available for any grinding operation the balance of power that is wasted will be known, and it should not then be impossible to devise means of reducing the waste.

GUERNSEY DOCK EXTENSIONS.

Messrs. Edmond Coignet, Ltd., have been appointed by Mr. F. E. Wentworth Sheilds, M.Inst.C.E., Docks Engineer of the Southern Railway, for the preparation of all the necessary working drawings and quantities for some extensive reinforced concrete works for the new dock extensions at Guernsey. Several new quays and wharfings are to be constructed, while the existing emplacements are to be widened and new offices and cargo sheds constructed. The new quays will be equipped with electric travelling cranes.

One of the principal objects of the new quays is to accommodate the new steamers of the Southern Railway Company. The work comprises:

Wharfing No. 1, 300 ft. long and 20 ft. wide, consisting of an upper and lower platform in reinforced concrete for unloading at all states of the tide. These platforms are to be supported by reinforced concrete cylinders. St. Julians' emplacement is to be extended by means of a south wall 350 ft. long and an east wall 325 ft. long. The intervening space between these two walls is to be filled up with sand excavated from the harbour. These two walls are to be constructed on the Coignet-Ravier system of sheet piles. There will also be two platforms in reinforced concrete supported in front by a row of reinforced concrete pillars and at the back by a mass concrete wall.

Wharfing No. 2 will consist of one platform only, 125 ft. by 15 ft. wide, constructed in reinforced concrete and supported by cylinders of the same material.

Wharfing No. 3 will have a length of 150 ft. by 30 ft., composed of two platforms of similar construction to Wharfing No. 1.

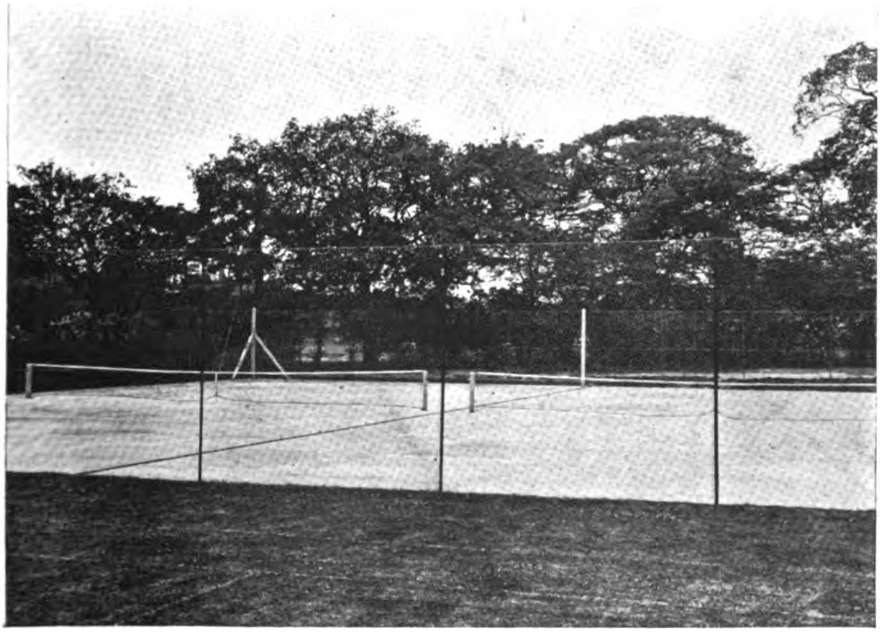
Staircases will be provided for communication between the upper and lower deck in each case. It is anticipated that tenders will be invited in the near future. The cost of the works, which are being undertaken by the Guernsey State Government, is estimated at about £107,000.

GREEN CONCRETE TENNIS COURTS.

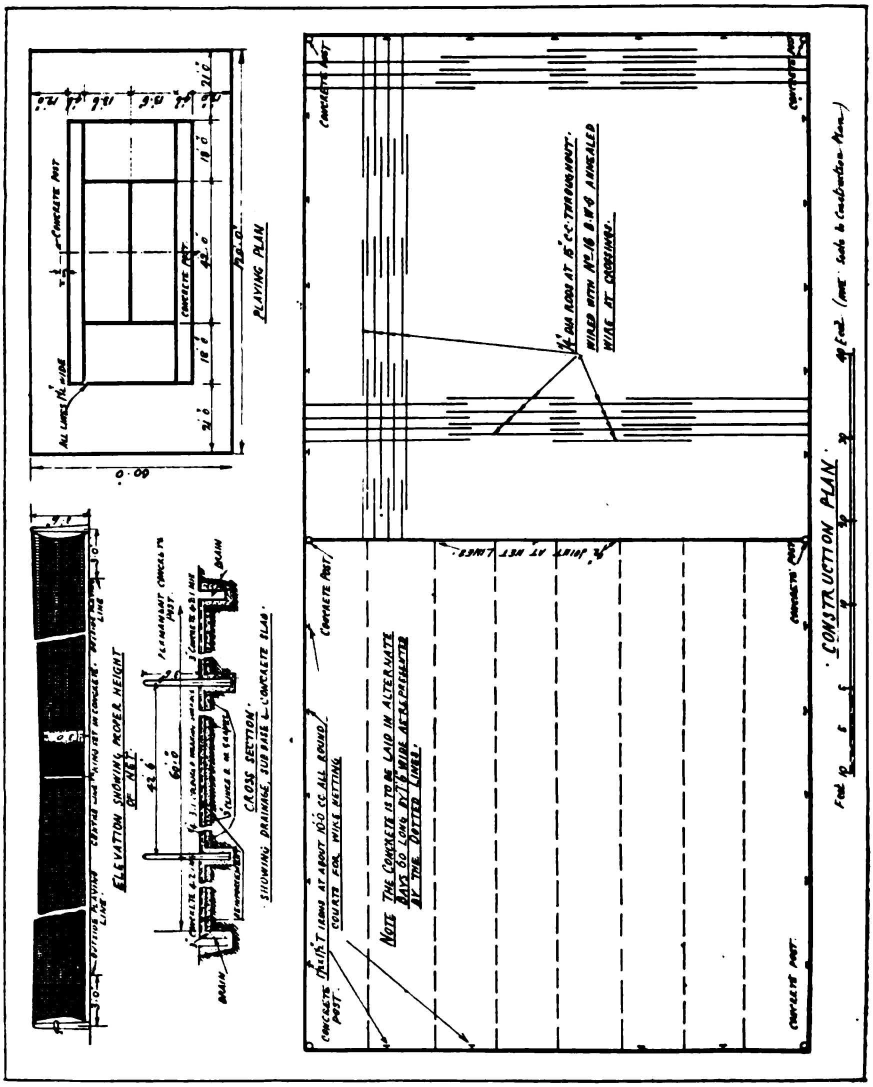
Two green concrete tennis courts, with an area of 118 ft. by 104 ft. including the surrounds, have recently been laid at the Associated Portland Cement Manufacturers' Sports Ground at Snaresbrook. The site was a bad one for the purpose, as a considerable amount of excavation had to be done and the sub-soil was clay, the natural drainage being towards the site of the courts. After the necessary excavation had been done so that all the loose soil was removed and the ground levelled, a trench for drainage was dug around the area and holes were dug for the necessary posts to carry the stop-netting and the posts for the tennis nets. Four inches of ordinary clinker was then spread and rolled with a ½-ton roller, the depth of clinker after rolling being about 3 in.

Before the concreting was begun 9-in. drain pipes to act as sockets were placed in the holes prepared for the posts and concrete placed between the exterior of the pipes and the surrounding soil. This was done because the posts had not been received before the concreting commenced.

The bottoms of the trenches were first concreted, allowing the necessary fall to carry away the water. The concrete slab was designed to be laid in alternate bays, consisting of 3 in. of mass concrete reinforced with ¼-in. rods running both ways, spaced 15 in. apart. Upon the mass concrete, whilst it was still in a plastic condition and before the initial set of the cement had taken place, coloured cement mortar ¼-in. thick was screeded on the top with a metal-shod wooden rule. The coloured mortar consisted of cement having the necessary percentage of green colour previously ground in at the works mixed with 3 parts of graded washed sand. The mass concrete consisted of 4½ parts of washed and graded broken flints, varying in size from about ⅜-in. down to coarse sand, 1½ parts of washed sand, to one part of cement. It was found by previous experiment that the ratio of broken flints to sand used gave the least percentage of voids. Both the mass concrete and the coloured mortar for the surface were mixed as dry as possible, only sufficient water being added to obtain plasticity. Immediately after



GREEN CONCRETE TENNIS COURTS AT SNARESBROOK.


ELEVATION SHOWING PROPER HEIGHT OF NET
OUTSIDE PLAYING LINE
CENTRE LINE
3'0"
42'6"
60'0"
PERMANENT CONCRETE POST
DRAIN
CROSS SECTION
SHOWING DRAINAGE SUB BASE & CONCRETE SLAB
ALL LINES 1 1/2" WIDE
CONCRETE POST
21'0
18'0
42'0
120'0
60'0
PLAYING PLAN
CONCRETE POST
1 1/2 x 1 1/2 T IRONS AT ABOUT 10'0 CC ALL ROUND COURTS FOR WIRE NETTING
NOTE THE CONCRETE IS TO BE LAID IN ALTERNATE BAYS 60 LONG BY 15 WIDE AS REPRESENTED BY THE DOTTED LINES
1/2" JOINT AT NET LINES
1/2" DIA RODS AT 18" C.C. THROUGHOUT WIRED WITH No 18 B.W.G ANNEALED WIRE AT CROSSINGS
CONSTRUCTION PLAN
Feet 10 5 0 10 20 30 40 Feet (Note Scale to Construction Plan)

Green Concrete Tennis Court at Snaresbrook.

the concrete was hard it was watered and kept continuously wet for at least a fortnight after the whole area was finished. After the slab was finished the concrete posts for holding the stop-netting and the tennis nets were concreted in.

The lines were painted on the surface with special white paint supplied by the Indestructible Paint Co., the work being done about a fortnight after the slab was finished. This paint was applied directly on to the concrete without any previous preparation.

A 6-in. drain was made between the two courts and covered with cast-iron gratings in order to allow better facilities for squeegeeing water off the surface from both sides of each court after heavy rain. It is found that it is a very simple operation to squeegee such water off the courts, in fact after the heaviest rain two men with squeegees can push the water off and the surface is sufficiently dry within about 10 minutes for play to take place. The surface as finished is excellent for playing, being very true and fast, and, being matt, is excellent as regards light.

This type of concrete court is in reality an "all-weather" court, being affected neither by frost, rain, nor drought, and has considerable advantage over other types of hard courts in that once laid there is practically no cost of upkeep, the expense of rolling, sweeping, and watering, to say nothing of the cost of water, being eliminated.

Experience gained in laying these two courts suggests that it might be advisable slightly to alter the design; it is suggested that instead of laying the concrete in bays of, say, 13 ft. by 13 ft. alternately, it would be better to make each bay half the length of the slab. Also, an appreciable saving could be made by using red oxide in order to give a red-coloured surface in place of the green as adopted.

The posts for holding the stop-netting were supplied by Messrs. Tidnams, Ltd., of Wisbech, and the posts for the tennis nets by the Atlas Stone Co., Ltd., of Cambridge. We understand that the owners of these courts would be pleased to permit those interested to play on them by appointment.

The following specification and estimate of the approximate cost of a standard court, where the site is level and foundation good, are based upon the cost of these two courts.

SPECIFICATION.

Excavate site and dig drains as shown on plan (if necessary). Spread suitable thickness of porous clinker according to subgrade and roll level and properly consolidate.

Drains to be concreted first and posts both for stop-netting and tennis net fixed, or holes dug for the latter and temporary drainpipes of suitable size in which the posts can be concreted placed in them.

Concrete for slab laid in alternate bays or strips of suitable size, say 60 ft. by 7 ft. 6 in. as follows :—

The whole court and surrounds shall be divided in half with a joint across the centre above which the tennis net will run. This can be done by fixing ½-in. boarding before concreting, and on withdrawal the space should be filled with a suitable jointing material, such as bitumen or felt treated with asphalte such as is used for dampcourses. The area to be concreted should then be divided into a number of bays of equal dimensions running from the joint at the centre to the extreme edge at the base of the court. Supposing the area to be laid is 120 ft. by 60 ft. and the width of each bay is 7 ft. 6 in., then each would measure 60 ft. by 7 ft. 6 in., making 16 bays for the whole area. One bay can easily be laid in one day; they should be laid alternately with the edges properly screeded off to leave a vertical face. This gives a complete butt joint between each bay to allow for expansion and contraction.

The reinforcement should be continuous and placed nearer the top than bottom.

Slab to be 3¼-in. thick made up of 3-in. concrete consisting of 4 parts clean graded broken ballast or flint—maximum size ⅜-in. or ½-in—2 parts best washed sand, 1 part cement. This to be mixed as dry as practicable and tamped in position.

Whilst the concrete is still plastic, and before the initial set of the cement has taken place, ¼-in. of green coloured cement mortar, mixed 3 parts best washed graded sand to 1 part green coloured cement, to be screeded on with a metal-shod rule; the mortar to be mixed as dry as practicable.

The screed is simply pushed backwards and forwards on the forms of the bay being laid, and mortar added in places as required until the surface is perfectly level. The concrete should be left to set, and afterwards it is important that the surface be kept continuously wet for at least a fortnight.

It is important to see that the green surface immediately after laying and until properly set is kept fully protected against rain by keeping it covered with a clean cover which does not actually touch the surface.

The topping of ¼-in. of green coloured mortar is made with sand in preference to granite chippings in order to get a matt surface.

A suitable hook for holding the centre of the tennis net should be embedded in the concrete.

The lines to be painted on two or three days after the concreting is finished. White paint can be used directly on the concrete, or the concrete can first be painted with a 50 per cent. solution of zinc sulphate in water allowing 48 hours or more to dry, and then applying ordinary paint in the usual way.

Size of Slab.	
Single court . . .	120 ft. by 60 ft. full size.
Two courts . . .	120 ft. by 108 ft. ,, ,,

APPROXIMATE COST OF A CONCRETE TENNIS COURT 120ft. BY 60ft.

	£	s.	d.	£	s.	d.
Green Cement						
2 tons 10 cwts. at £18 per ton . . .				45	0	0
Portlant cement						
14 tons at £3 1*s.* 6*d.* . . .	43	1	0			
Hire of 154 sacks at 3*d.* . .	1	18	6			
				44	19	6
Sand (washed)						
30 tons at 12*s.* 3*d.*				18	7	6
Ballast (washed)						
60 tons at 12*s.* 3*d.*				36	15	0
Clinker						
66 tons at 5*s.* 3*d.* delivered	17	6	6			
*Laying and rolling . . .	8	0	0			
				25	6	6
Reinforcement						
17½ cwts. mild steel round rods	12	0	7			
*Carting and handling . .	1	2	0			
				13	2	7
Painting				2	10	0
Labour, supervision, and shuttering . .				120	0	0
				£306	1	1

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* Costs against these items are the maximum and in most cases could be very much reduced, or in some cases eliminated, depending on the nature of the sub-soil.

PROPOSED SEVERN BARRAGE.

THE Government has decided to proceed at once with certain preliminary investigations in order to ascertain the feasibility of the scheme for using the tidal power of the river Severn for the production of electrical power by the erection of a barrage across the river. The Lord President has appointed Messrs. G. S. Albright (Chairman), A. H. Gibson, M.Inst.C.E., G. W. Lamplugh, F.R.S., Maurice Wilson, A.M.Inst.C.E., and J. S. Flett (Director, Geological Survey and Museum) as a committee to supervise and direct the work.

The feasibility of the Severn scheme turns upon the possibility of finding satisfactory foundations for a barrage. Accordingly the first stage of the investigation will involve: (*a*) The study by the Geological Survey of the stratigraphical formations in the neighbourhood of the sites suggested for the erection of the barrage; (*b*) taking preliminary soundings with a view to determining the contour of the river bed at the sites; and (*c*) preliminary measurements of the flow of water at different states of the tide.

Meanwhile, Sir Maurice Fitzmaurice and Sir John Purser Griffith have been invited by the Lord President to submit a joint report before the end of this year as to the possibility of constructing a barrage on one or more of the sites suggested on the assumption that safe foundations exist. The data which will be provided as a result of the geological and hydrographical investigations already mentioned will be placed at their disposal. The staff of the Geological Survey have already begun the inquiry entrusted to them, and their report will probably be ready for submission to the Committee before the end of September.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ½ in. mesh	,,	15	0
Best British Portland Cement	per ton 58s. to	63	0
"Ferrocrete" Portland Cement	10s. per ton extra		

BOARDING FOR SHUTTERING—

		Sawn.		Wrot.	
		s.	d.	s.	d.
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

SAWN TIMBER FOR STRUTS AND SUPPORTS—

3 in. by 4 in.	from £24 10s. per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £25 10s. ,, ,,

MILD STEEL RODS FOR REINFORCEMENT—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
9/16 in. to ½ in. Rounds	,,	13	6
⅜ in. Rounds	,,	14	6
¼ in. Rounds	,,	15	6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

PORTLAND CEMENT CONCRETE WELL MIXED WITH CLEAN WATER IN PROPORTION 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per yard cube	45	6
Do.	do.	in columns	,, ,,	50	6
Do.	do.	in beams	,, ,,	50	6
Do.	do.	in floor slabs 4 in. thick	per yard super	5	4
Do.	do.	in floor slabs 6 in. thick	,, ,,	7	11
Do.	do.	in floor slabs 9 in. thick	,, ,,	11	6
Do.	do.	in walls 6 in. thick	,, ,,	8	2

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

STEEL REINFORCEMENT, INCLUDING CUTTING, BENDING AND PUTTING INTO POSITION AND SECURING WITH STOUT BINDING WIRE—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	24	0
,, 9/16 in. to ½ in.	,,	23	0
,, ⅝ in. to 2⅞ in.	,,	22	0

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.*

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.*

SHUTTERING—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	55	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	51	0
Do. do. in small quantities	per ft. super	0	9½
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last, in narrow widths	,, ,,	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	,, ,,	1	1
Do. do. as last, in narrow widths	,, ,,	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/8 per hour; Labourers on building works, 1/3; Operators on concrete mixers and hoists, 1/4.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

PROSPECTIVE NEW CONCRETE WORK.

ASHINGTON.—*Road.*—The Ashington Council and Morpeth R.D.C. have a scheme in hand for the construction of a road between Ashington and Ellington, estimated to cost £44,100.

BEXHILL.—*Bridge.*—The T.C. has approached the Southern Railway Co. with regard to the construction of a ferro-concrete bridge at Manor Road, estimated to cost £7,500.

BIRMINGHAM.—*Reservoir.*—The Corporation proposes to include in its relief scheme the construction of a reservoir, estimated to cost £500,000.

BRADFORD.—*Reservoirs.*—The Water Committee proposes to cover the Idle Hill and Thornton Moor reservoirs with reinforced concrete, at an estimated cost of £10,000.

BROUGHTY FERRY.—*Road.*—The Council is considering the question of laying a road from Tuppenny John's Corner to Douglas Terrace, at an estimated cost of £50,000.

BROWNHILLS.—*Houses.*—The U.D.C. has applied for sanction to borrow £44,838 in connection with a new housing scheme.

BURTON-ON-TRENT.—*Houses.*—The Corporation has applied to the M.H. for sanction to a loan in connection with the erection of 31 houses.

BURY.—*Paving.*—The T.C. proposes to pave the open market with concrete, at an estimated cost of £2,529.

CANKLOW.—*Bridge.*—The Rotherham R.D.C. has a scheme on hand for the construction of a bridge at Canklow.

CARDIGAN.—*Road.*—The T.C. proposes to construct a road beyond "Webley Arms," at an estimated cost of £790.

CLITHEROE.—*Houses.*—The Corporation proposes to build 140 houses in Pendle Road.

DARWEN.—*Road.*—The Lancashire C.C. has under consideration the construction of a road from Darwen to Bolton.

DONCASTER.—*Concrete Houses.*—The T.C. proposes to erect 200 concrete houses.

DUMFRIES AND MAXWELLTON.—*Bridge.*—The Town Councils have received sanction to construct a ferro-concrete bridge over the Nith, at an estimated cost of £35,000.

FILEY.—*Sea Defence Works.*—The U.D.C. proposes to carry out sea defence works, and has applied for a grant towards the cost, estimated at £12,000.

FROME.—*Road.*—The Frome R.D.C. has instructed the Surveyor to prepare plans for the laying of a new road from Rodden Lake Bridge to Wallbridge.

GLASGOW.—*Houses.*—The Finance Committee recommends the Corporation to apply for sanction to borrow £3,000,000 in connection with housing schemes.

GOODWICK.—*Bridge.*—The U.D.C. proposes to construct a bridge at Goldwig Villas.

HILTON.—*Houses.*—The Cannock R.D.C. proposes to erect 30 houses at Hilton.

HULL.—*Houses.*—The Finance Committee has recommended the issue of bonds for the raising of £300,000 for the construction of houses.

HUNSTANTON.—*Sea Defence Works.*—The U.D.C. has a scheme in hand for sea defence works, estimated to cost £5,560.

KESWICK.—*Bridge.*—The Cumberland C.C. proposes to construct a bridge over the Greta, at an estimated cost of £6,400.

KIRTON HOLME.—*Bridge.*—The Holland C.C. proposes to reconstruct Beck Bridge in ferro-concrete, at an estimated cost of £1,500.

LEEDS.—*Reservoirs.*—The Corporation proposes to construct two reservoirs in the Laver Valley.

LONDON.—*Houses.*—The L.C.C. Housing Committee recommends the erection of 20,000 houses under the new Housing Act.

LOUGHBOROUGH.—*Concrete Houses.*—The T.C. has submitted a scheme to the M.H. for the construction of concrete houses.

MABLETHORPE.—*Sewage Works.*—The U.D.C. has applied to the M.H. for sanction to borrow £1,500 for sewage disposal works.

MAIDSTONE.—*Houses.*—The Corporation proposes to erect 44 houses on the Coombe Farm estate.

MANSFIELD.—*Concrete Houses.*—The T.C. has under consideration a scheme for the construction of concrete houses.

MOLESEY.—*Sewage Works.*—The U.D.C. is considering a scheme for improving the sewage disposal works, at a cost not exceeding £3,000.

Newport.—*Road.*—The Corporation proposes to construct a road from Evesell Park to Woodland Park Road.

Northam.—*Sea Defence Works.*—The U.D.C. has applied to the M.H. for sanction to borrow £6,000 in connection with the prevention of coast erosion.

Ovingdeane.—*Sea Defence Works.*—The East Sussex C.C. proposes to expend £1,569 on sea defence work.

Poole.—*Houses.*—The Corporation has applied to the M.H. for sanction to erect 100 houses.

Radcliffe.—*Road.*—The T.C. proposes to construct a road from Radcliffe to Manchester.

Salcombe.—*Reservoir.*—The U.D.C. has applied to the M.H. for sanction to construct a reservoir with a capacity of 300,000 gallons.

Selby.—*Bridge.*—The West Riding C.C. proposes to build a bridge in place of the old stone bridge, at a cost of £15,000.

Shanklin.—*Groyne.*—The U.D.C. proposes to construct a new groyne.

South Kirkby.—*Concrete Houses.*—The Parish Council has approached the Hemsworth R.D.C. with a view to erecting 100 concrete houses at South Kirkby.

Suckley (Worcs.). — *Bridge.* — The Martley Council proposes to erect a concrete bridge in place of the existing bridge at Suckley.

Swansea.—*Bridge.*—The Corporation proposes to construct a bridge over the Tawe.

Swansea.—*Houses.*—The T.C. proposes to erect 50 houses on the Townhill estate.

Walsall.—*Houses.*—The Borough Surveyor has been instructed to prepare plans for the construction of 100 houses.

Walton.—*Concrete Raft.*—The Middlesex C.C. proposes to strengthen the bridge at Walton by constructing a concrete raft on the southern approach, at an estimated cost of £800.

Warrington.—*Concrete Houses.*—The T.C. has instructed the Housing Committee to prepare schemes for the erection of concrete houses.

Wellington.—*Houses.*—The R.D.C. has applied to the M.H. for sanction to erect 40 houses.

Worthing.—*Groynes.*—The Corporation has applied to the M.H. for sanction to borrow £2,000 for the construction of two reinforced concrete groynes.

York.—*Bridge.*—The T.C. proposes to submit to the M.T. a scheme for the construction of a bridge over the River Ouse at Clifton Scope, estimated to cost £73,500.

York.—*Concrete Houses.*—The Housing Committee recommends the erection of 300 concrete houses.

TENDERS ACCEPTED.

Aberdeen.—*Reservoir.*—The T.C. has accepted the tender of Messrs. Clark and Chapman, Aberdeen, at £42,215, for the construction of a concrete covered reservoir at Airy Hall, Cults.

Bedford.—*Buildings.*—The Corporation has accepted the tender of the Luton Building Co., Church Street, Luton, for the erection of reinforced concrete buildings and coal bunkers.

Bedwas.—*Sewer.*—The U.D.C. has accepted the tender of Mr. W. E. Evans, Newport, at £549 12*s.*, for the construction of a reinforced concrete sewer at Tywywern Road.

Bo'ness.—*Footpaths.*—The T.C. has accepted the tender of Mr. D. Aitken, Bo'ness, at £1,082 17*s.*, for laying concrete footpaths and hydraulic-pressed concrete paving blocks.

Bournemouth.—*Pierhead.*—The T.C. has accepted the tender of Messrs. F. Bevis, Ltd., at £10,250, for reconstructing the pierhead in reinforced concrete.

Bradford.—*Bridge.*—The T.C. has accepted the tender of Messrs. Peter Lind & Co., at £3,700, for the construction of a ferro-concrete bridge at Esholt.

Doncaster.—*Bridge.*—The Corporation has accepted the tender of Messrs. Hodkin & Jones, at £150, for the reconstruction of the Larger Bridge in reinforced concrete.

Dunmow. — *Retaining Wall.* — The R.D.C. has accepted the tender of Messrs. J. Day & Son, Bishop's Stortford, at £382 10*s.*, for the construction of a concrete retaining wall at Mill Pond, Felstead.

Eastleigh (Hants.). — *Bridge.* — The U.D.C. has accepted the tender of Mr.

J. Douglas, Southampton, at £1,391, for widening a bridge in ferro-concrete and the construction of retaining walls.

EDINBURGH.—The T.C. has accepted the tender of Messrs. Bain & Brown, Leith, at £54,480, for the construction of a new sewer and promenade at Portobello, including 1,316 lineal yds. of 4-ft. by 6-ft. concrete sewer, concrete sea wall, and 366 lineal yds. of 3-ft. diameter concrete sewer.

ERPINGHAM (NORFOLK.).—*Cottages.*—The R.D.C. has accepted the tender of Messrs. Norfolk Concrete Products, Ltd., Stalham, at £895, for the erection of two cottages.

FORT WILLIAM.—*Pier, etc.*—The British Aluminium Co., Ltd. has accepted the tender of Messrs. Balfour, Beatty & Co., Ltd., for the construction of a reinforced concrete pier and approach viaduct at Fort William.

GOOLE.—*Water Tower.*—The U.D.C. has accepted the tender of Messrs. H. Arnold & Son, Doncaster, at £23,161, for the construction of a ferro-concrete water tower with a capacity of 750,000 gallons.

GREENFORD.—*Bridge.*—The Middlesex C.C. has accepted the tender of Messrs. A. Jackaman & Sons, Slough, at £10,792 17*s.* 1*d.*, for the construction of a reinforced concrete bridge over the Grand Junction Canal.

GRIMSBY.—*Road Works.*—The T.C. has accepted the tender of Messrs. J. H. Thompson & Sons, at £33,658, for reconstructing Laceby Road in ferro-concrete.

PLYMOUTH.—*Sewage Works.*—The T.C. has accepted the tender of Messrs. Maben & Waldron, at £345 10*s.* 4*d.*, for the construction of sewage disposal works at Udal Torre.

ROTHESAY.—*Sewage Works.*—The T.C. has accepted the tender of Messrs. Peter McBride & Co., Port Glasgow, at £50,000, for improvements to the sewage disposal system.

SHIPLEY.—*Sewage Works.*—The U.D.C. has accepted the tender of Messrs. H. Sugden & Son, at £212 6*s.* 6*d.*, for reinforced concrete work at the sewage works.

STOKE NEWINGTON (LONDON).—*Foundations.*—The B.C. has accepted the tender of Messrs. S. Goodall & Sons, at £280, for foundation work at the electricity transformer station.

TABLEY.—*Bridge.*—The Cheshire C.C. has accepted the tender of the Reinforced Concrete Construction Co., Manchester, at £1,629, for reconstructing the bridge at Tabley.

TRETTON.—*Bridge.*—The Isle of Ely C.C. has accepted the tender of the Yorkshire Hennebique Contracting Co., Ltd., Leeds, at £2,508, for the construction of a bridge at Tretton.

YORKSHIRE.—*Bridges.*—The East Riding C.C. has accepted the tenders of the Yorkshire Hennebique Contracting Co., Ltd., at £1,225 and £2,879 for the construction of reinforced concrete bridges at Fraisthorpe and Lissett.

TRADE NOTICES.

MANY and various are the methods adopted by business firms to keep their names and their products or the services they have to offer before potential customers, and in the preparation of such advertising mediums there has sprung up a large and highly-specialised profession. However attractive its appearance it is safe to say that not one in ten of the circulars received by a professional or business man are more than glanced at before they are dispatched to the waste-paper basket. If it is to be kept by the recipient, publicity matter must contain something of interest beyond a bare statement of the nature of a business plus the too often extravagant claims of the cheapness or excellence of the service or goods offered. This has been realised by Messrs. Trollope & Colls, Ltd., the well-known builders, of No. 5, Coleman Street, London, E.C., who have sent us the first of a series of bulletins which they are issuing to architects and engineers and which we venture to think will be carefully filed away for reference for years to come. As befits the dignity of a firm with the standing of Messrs. Trollope & Colls, there is no blatant advertising whatever in the bulletin. It deals with water towers built in reinforced concrete, and tables and charts are given from which one may see at a glance the approximate cost of such water towers of various capacities and heights, approximate costs per 1,000 gallons for towers of different height, and the relation between the cost of storage per 1,000 gallons and the total capacity of the tower for various heights above ground. A photograph, plan, and section of a typical reinforced concrete water tower are given, together with some notes on the subject. If the other bulletins to be issued are as interesting as the first the series will form a valuable work of reference which should be in the possession of all who in the course of their business are called upon to provide sketch designs and approximate estimates of various reinforced concrete structures. We understand that copies will be sent free on request by the Engineering Department of Messrs. Trollope & Colls, Ltd.

VAST and beautiful buildings are erected for the retail trade, unsightly hoardings are being banished from the countryside, some of the best examples of the painters' art are in the cause of propaganda. Truly ideas on publicity have undergone a revolutionary change during the past few years. It is realised that a mean building, a catalogue poorly put together and badly printed, is liable to be taken as typical of the products of a firm, as very often it is. One of the best produced volumes we have seen for some time has been issued by Messrs. Holloway Brothers (London), Ltd., builders, of Bridge Wharf, Grosvenor Road, London, S.W.1, entitled "Ancient and Modern Building," by Mr. Sydney J. Holloway. Handsomely bound, printed on heavy art paper, and containing a large number of excellent illustrations, the volume in an interesting manner describes the progress of the building art from the cave dwellings of the Stone Age to the present day, each phase being illustrated wherever archæological researches provide sufficient evidence on which to produce a conjectural sketch which may be assumed to give with some degree of accuracy an idea of the appearance of a hut circle, a neolithic camp, and other rude dwellings of past ages. Of a later period, photographs are given of some of the few examples which remain to us of sixteenth-century buildings, such as Moreton Old Hall, Cheshire. The account of early buildings occupies the first 25 pages of the volume, and it is a testimony to the extent and variety of the activities of Messrs. Holloway Brothers that it has been possible to provide illustrations for the remaining 100 pages from buildings which have been restored or erected by them. The earliest example which has been made stable at their hands is Hexham Abbey, founded about 674 and restored under the direction of the late Temple Moore, F.R.I.B.A., in 1908. Rushton Hall and West Lavington Manor House are typical of Tudor and Jacobean domestic works which have been restored by the firm under distinguished architects. The new Old Bailey, the Armenian Church in London, a housing scheme for the Wandsworth Borough Council, Messrs. Whiteley's stores, the General Post Office, the Government buildings in Gt. George Street, London Wall Buildings, Magnet House in Kingsway, the United Universities Club in Pall Mall, No. 22, Grosvenor Square, Caxton House, the Royal National Orthopædic Hospital, and a number of country houses, war memorials, and engineering works are illustrated as typical of the firm's achievements in monumental, commercial, and domestic building; each illustration is accompanied by some interesting historical notes, which many will wish had been given at greater length. The make-up of the volume has been attractively arranged, and it is with pleasure we note that the name of the producer is given as well as those of the author and printer.

MESSRS. BRUNNER, MOND & CO., Ltd., of Northwich, have issued a 16-page booklet dealing with the application of silicate of soda for hardening concrete surfaces. After quoting various authorities on the subject, the book gives the following instructions for treating concrete roads and floors with P.84 grade silicate of soda: (1) It is important that the silicate of soda should be mixed with four times its volume of water before it is applied to the concrete; if a stronger solution is used adequate penetration of the pores of the concrete cannot take place, and the maximum benefit of the treatment will not be obtained. (2) Before treatment the concrete surface must be clean, free from grease and dust, and comparatively dry. (3) The concrete should be well watered with the dilute Silicate, and a soft brush or mop used to spread the solution evenly over the surface, care being taken to keep the concrete wet long enough to ensure penetration. (4) The concrete should be allowed to dry for twenty-four hours, and the process repeated. (5) After another period of drying, a third treatment should be given in the same way. (6) The quantity required varies slightly according to the porosity of the concrete; usually 1 cwt. of P.84 silicate is sufficient for the complete treatment of 300 sq. yds.

Mr. H. C. Golding has joined the staff of Messrs. David Weston & Company, Ltd., reinforced concrete engineers, 46, High Street, Croydon.

A new company, known as Millars' Machinery Co., Ltd., has been formed to take over the Machinery Department hitherto carried on by Messrs. Millars' Timber and Trading Co., Ltd. The directors of the new company are all directors of Messrs. Millars' Timber and Trading Co., Ltd., by whom all the share capital in the new company is held.

Messrs. Monolithic, and General Constructions, Ltd., have removed from 7, Prince's Street, Westminster, to Holophane House, Elverton Street, Vincent Square, London, S.W.1. Telephone number: Victoria 6487; Telegrams: Monagena, Phone, London.

RECENT PATENT APPLICATIONS.

192,413.—M. Righetto and C. Zorzi: Reinforced concrete sleepers.
211,155.—H. Conradi: Centrifugal manufacture of reinforced concrete pipes.
216,682.—R. K. Abbott: Cement-integrated fibrous sheet.
216,951.—J. Broadfoot & Sons, Ltd., and J. G. Robertson: Cement and filling material.
216,952.—J. Broadfoot & Sons, Ltd., and J. G. Robertson: Plastic material for the production of moulded articles.
217,343.—J. H. Amies: Cementitious composition.
217,388.—C. Pickstone: Manufacture of mortar, artificial stone, and concrete.
217,478.—E. Bivet and T. E. Firth: Concrete floor construction.
217,633.—E. C. R. Marks (Master Builders Co.): Process and composition of matter for colouring mortars and concretes.
218,027.—J. A. Davenport: Reinforced concrete beam construction.
218,159.—R. H. Rogers: Concrete paving and floors.
218,202.—J. Fowler and Co. (Leeds), Ltd. and C. M. Wilcock: Loading apparatus for concrete.
218,760.—T. Debenham: Manufacture of concrete pipes.
218,810.—M. Haramiishi: Ferro-concrete walls.

NEW COMPANY REGISTERED.

Concrete Aggregates, Ltd. (198,706). Registered June 18. Ballast, sand, gravel, flint, grit, stone, and shingle merchants; dealers in concrete and reinforced concrete. Nominal capital: £20,000 in 20,000 shares of £1 each. Directors: W. Brice, 161, Grosvenor Road, S.W.1 (Go. Director). Qualification of Directors, £100; remuneration to be voted by Company.

Kingston By-pass Road.

Messrs. The Ham River Grit Co., Ltd., of 161, Grosvenor Road, Westminster, S.W.1, inform us that they supplied the aggregate and sand for the new Kingston By-pass Road, illustrated and described in our last issue.

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Price 1s. 6d. net. OCT 27 1924 *Annual, Post Free, 18s.*

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

OCTOBER 1924 VOL. XIX No. 10

NINETEENTH YEAR OF PUBLICATION

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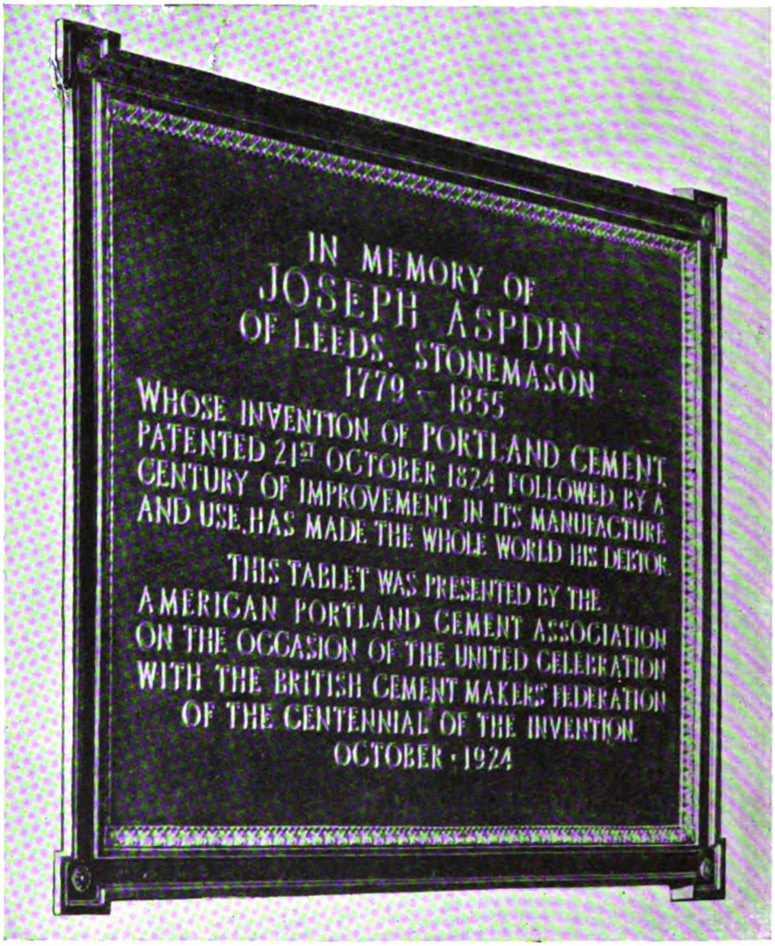

IN MEMORY OF
JOSEPH ASPDIN
OF LEEDS, STONEMASON
1779 – 1855
WHOSE INVENTION OF PORTLAND CEMENT,
PATENTED 21ST OCTOBER 1824 FOLLOWED BY A
CENTURY OF IMPROVEMENT IN ITS MANUFACTURE
AND USE, HAS MADE THE WHOLE WORLD HIS DEBTOR.

THIS TABLET WAS PRESENTED BY THE
AMERICAN PORTLAND CEMENT ASSOCIATION
ON THE OCCASION OF THE UNITED CELEBRATION
WITH THE BRITISH CEMENT MAKERS' FEDERATION
OF THE CENTENNIAL OF THE INVENTION.
OCTOBER · 1924

TABLET TO THE MEMORY OF JOSEPH ASPDIN, UNVEILED IN LEEDS TOWN HALL ON SEPTEMBER 6, TO MARK THE CENTENARY OF HIS INVENTION OF PORTLAND CEMENT.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XIX. No. 10. LONDON, OCTOBER, 1924.

EDITORIAL NOTES.

A HUNDRED YEARS OF PORTLAND CEMENT.

WHAT changes the world has seen since the year 1824. A hundred years ago the country, as now, was recovering from the effects of long and costly Continental wars, and, also as at present, necessity demanded that new sources of wealth be found and new methods of production discovered to make good the loss of men and money caused by war. It was, in fact, the beginning of the " industrial revolution " of the nineteenth century which has completely changed the mode of life and thought of people all the world over. The past century has seen more progress in science, industry, and learning than the whole of the previous centuries of which we have record. In the 1820's trade unionism was beginning to be talked about by a few men of advanced thought in England and France ; in 1824 Stephenson was " perfecting " his famous " Rocket " which caused such a sensation when first run in public in the following year, when the bulk of the public looked upon it with either ridicule or superstitious awe ; in 1824 Aspdin filed his patent specification for what he called " Portland cement." When we see a Labour Government in power at Westminster, a network of railways all over the country and trains speeding along at seventy miles an hour, and the skyscrapers and other structures which the Portland cement we know to-day has made possible, it is difficult to realise that so much has been achieved in one century. In the history of civilisation a hundred years is but a brief period. We have centenarians still with us who were alive when these epoch-making movements and inventions first took shape and have lived to see their effect after a century of development, who were in the prime of life when the uses of electricity were discovered and the telephone invented, and who in their old age have heard " wireless " concerts tapped from an aerial in the back garden.

The history of Portland cement, with which we are chiefly concerned here, is bound up so intimately with so many branches of human activity on land and sea that any record of its development must necessarily be an account of the life and industry of the times. Although it is perhaps too much to say that without Portland cement progress would not have been so great, it is certain that without its aid progress would not have been so easy. Steamships are invented and grow in size beyond the capacity of the docks to accommodate them, so docks are extended or new ones built of concrete ; railways need bridges and linings for tunnels, and concrete is the material chiefly used ; heavy and fast vehicles in a constant stream are required to transport people and goods, and concrete is the most suitable foundation for the roads which bear them; larger and higher buildings are necessary to carry on manufacture and for office accommodation, and when they are not built entirely of concrete this material enters largely into their construction; and so on, from cathedrals to cottages, from the biggest warehouses in the world to fence-posts and garden ornaments, in most phases of the developments which have changed the country from what it was in the days of George IV to its present state in the reign of George V.

It was, however, a very different material from the scientifically-produced product we know at the present time which in 1824 Joseph Aspdin, a Leeds bricklayer, called "Portland cement," probably because more than fifty years before Smeaton had found that a mixture of limestone and clay when burnt made a cement which would "equal the best Portland stone in solidity and durability." Aspdin's original patent of December 18, 1824, suggests that his methods were of an extremely haphazard and tentative nature. It is stated, for instance: "I take a specific quantity of limestone, such as that generally used for making or repairing roads, and I take it from the roads after it is reduced to a puddle or powder." These road scrapings he calcined and mixed with "a specific quantity" of argillaceous earth or clay and water to a state approaching impalpability, but no definite proportions are mentioned. It is probable, however, that the secrecy with which he enshrouded his works, allowing none but his own workmen to enter, and taking part personally in the loading of every kiln, hid a greater knowledge than he was prepared to make public in a patent specification. In 1825 he erected a factory at Wakefield, which after his death in 1855, at the age of 76 years, was carried on by his son James, while his other son, William, started a works at Northfleet. In its early days, however, the new Portland cement did not find favour with engineers for constructional work, although it appears to have been considerably used for stucco work. The first important work in which it was used was the Thames Tunnel, started in 1838, for which Brunel obtained Portland cement from Aspdin's works at Wakefield, in spite of the fact that Aspdin's cement cost 20*s.* to 22*s.* per cask at the works, while Roman cement could be bought in London at 12*s.* per cask. Brunel was no doubt aware of the economy to be obtained with this material, for in 1843 tests were made with the two materials which showed that the strength of the Portland cement of that time, mixed with sand in the proportion of 1 to 3, was more than double that of Roman cement mixed with one part of sand. In 1859 the recognition of the value of Portland cement by Mr. John Grant, Engineer to the Metropolitan Board of Works, who decided to use it for the construction of the London drainage works then undertaken, undoubtedly gave a great impetus to its more general use. It is interesting to note that in 1862 a mixture of 1 part of the Portland cement used by Grant and 3 parts sand had a tensile strength at 7 days of 20 lbs. per square inch, compared with 750 lbs. per square inch obtained with a similar mixture of the Portland cement of 1924. A vast amount of research and invention in manufacture has contributed to this great improvement in quality, no doubt the most important being the invention of the first rotary kiln by Crampton in 1877. Quick-hardening cements are now being manufactured, and it is to be anticipated that the work of the British Portland Cement Research Association and others will result in still further improvements in the near future. What will happen during the next hundred years no one can say, but the concrete age is as yet only dawning, and the world's output of cement is already over fifty million tons per annum.

On page 629 of this issue will be found a review of a new book, by Mr. A. C. Davis, which has been specially written and published to commemorate the centenary of the invention of Portland cement one hundred years ago, and which gives a full account of the remarkable history of the growth both in quality and output of the material.

TRAINING THE CONCRETER.

NEGLECT in the education and training of the men actually engaged in the erection of reinforced concrete structures is a feature of the concrete industry on which we have frequently commented. It is often stated that any unskilled labour is suitable for concreting, but, except perhaps in the case of laying mass concrete in situations where thorough supervision is a simple matter, this is far from the truth. Reinforced concrete depends for its strength largely upon the proper placing of the steel, and designers go to the utmost pains in preparing drawings showing the exact position of each bar or stirrup in order to secure the greatest efficiency with the most economical use of material. In the result, however, it depends largely upon the concreters on the job whether the intentions of the designer are realised, for by their intelligence in placing the reinforcement in the exact positions specified and ramming the concrete around them in a thorough manner the operatives and their supervisors can make ineffective the most carefully-prepared design. Fortunately most of the foremen of the large contracting firms are generally men of considerable experience in whose hands the most intricate work is quite safe, but with a growing industry such as this, for which there is a lamentable lack of educational facilities in the technical schools up and down the country, there is a grave risk of men with insufficient knowledge of the subject being placed in charge of important operations. In any walk of life a deficiency of courses of instruction readily available naturally leads to the acquirement of knowledge by experience, which under able guidance is perhaps the best school in which skill can be attained, but if the readiness to teach and the willingness to learn be not keen it may lead to disastrous results when the learner attempts to supervise work of whose nature he has but a hazy idea.

Apart from supervision, as concreting comes to be looked upon more as a skilled operation than as work which any unskilled labourer can perform, when the savings which can be effected by scientific proportioning and mixing and careful placing are fully realised, it may be considered a matter for regret that concreters have been content to remain in the ranks of the unskilled or semi-skilled; the bricklayer, carpenter, plumber, plasterer, in fact practically all engaged in building work except those who fetch and carry, and the concreter, are looked upon as skilled men for whose occupation an apprenticeship is necessary, and it is rather a matter for surprise that concreters have not put forward a claim to occupy a similar position. It is certain that if men with proper training were demanded, and concreters, raised from the status of labourers, took that added interest in their work which comes to a man when he is looked upon as a craftsman, we should see less of the shipshod work too often noticeable in the streets to-day. Whether or not this point of view is accepted, the fact remains that there is an absence of positive knowledge on the subject amongst the operatives usually employed for concreting which should be remedied in the best interests of the industry.

It is with these thoughts in mind that we give in this issue the first of a series of articles by Mr. Albert Lakeman, M.S.A., M.I.Struct.E., Honours Medallist in Construction, late lecturer at the Woolwich Polytechnic, on the most elementary principles of reinforced construction. Our original intention was to publish these articles in book form so that by studying them in the simple language in which they are written and gaining a thorough knowledge of the *raison d'être* of all he did the foreman and operative engaged on concrete construction would be able to take a more intelligent interest in the work. In a technical publication such as this perhaps such articles are out of place, but it occurs to us that many of our readers might like to pass them on to those engaged in carrying out their designs or in their employ. We propose, therefore, also to give the whole of Mr. Lakeman's book in this journal in instalments, and afterwards publish them in book form at a popular price which will be within the reach of the body of men for whom they have been written.

ROAD SURFACES.

So much money has been spent on road works during the past few years that it seems rather late in the day to appoint a committee to consider what is the best surface for the requirements of modern traffic. However this may be, we welcome the decision of the Government to inquire into the matter, and have no doubt that the findings will counteract the statements which so often get into print accusing concrete surfaces of being slippery. We have taken the trouble to visit some of the spots complained of on this score, and in each case we have found that the surface is not concrete at all, but some other road surfacing material. We hope the members of the committee will personally motor over sections of roads with different surfaces at a time when conditions are conducive to skidding and see for themselves that it is practically impossible to skid a car on a concrete surface.

MOMENTS IN CONTINUOUS BEAMS HAVING A VARYING MOMENT OF INERTIA.

By CHARLES S. GRAY, B.Sc.(Eng.) A.M.I.Struct.E.

THE usual form of Clapeyron's Theorem of Three Moments for Continuous Beams is

$$M_1 l_1 + 2M_2(l_1 + l_2) + M_3 l_3 = 6\left\{\frac{A_1 x_1}{l_1} + \frac{A_2 x_2}{l_2}\right\}$$

wherein l_1, l_2 = lengths of any two consecutive spans.
M_1, M_2, M_3 = bending moments at supports.
A_1, A_2 = areas of respective free bending moment diagrams.
x_1, x_2 = distances of centres of gravity of free bending moment diagrams from supports 1 and 3 (*see Fig.* 1).

This equation assumes that EI is constant throughout the length of the beam, a condition rarely attained in practice since I will vary considerably from point to point along the span. To take account of this variation, the quantity I must be left under the integral sign in the mathematical derivation of the formula * and an expression may then be obtained giving the relationship between the three consecutive moments and the loads in the two spans under consideration, in which the various integrals containing I are solved by substituting the varying values of this quantity.

In this article the author proposes to use a graphical solution of the question, since in general the variations of I are not readily expressed in the form of a mathematical equation.

For the purpose of example we will assume a continuous beam of two spans respectively 20 ft. and 16 ft. with a uniform load of 3,000 lbs. per lineal foot (including the weight of the beam) over both spans.

Then maximum free moment on long span

$$= 0{\cdot}125Wl \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(ii)}$$
$$= 3{,}000 \times 20^2 \times 1{\cdot}5.$$
$$= 1{,}800{,}000 \text{ inch lbs.}$$

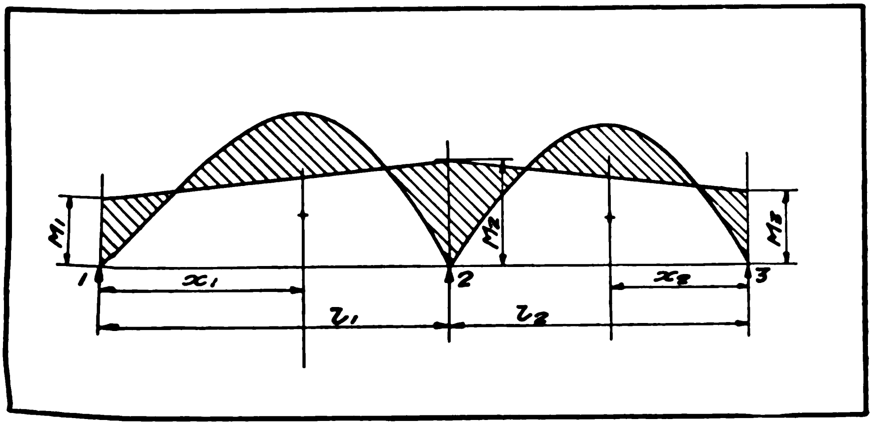

FIG. 1.

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* See any standard textbook on the Theory of Structures, etc.

Maximum free moment on short span (l being the long span)

$= 0{\cdot}080Wl$ . . . . (iii)

$= 3{,}000 \times 20^2 \times 0{\cdot}96.$

$= 1{,}152{,}000$ inch lbs.

Support moment

$= 0{\cdot}105Wl$ . . . . (iv)

$= 3{,}000 \times 20^2 \times 1{\cdot}26.$

$= 1{,}512{,}000$ inch lbs.

Maximum positive moment in long span

$= 0{\cdot}078\ Wl$ . . . . (v)

$= 3{,}000 \times 20^2 \times 0{\cdot}936.$

$= 1{,}123{,}000$ inch lbs.

Maximum positive moment in short span

$= 0{\cdot}036\ Wl$ . . . . (vi)

$= 3{,}000 \times 20^2 \times 0{\cdot}432.$

$= 518{,}000$ inch lbs.

The Bending Moment Diagram then comes as in *Fig.* 2.

(For the value in expressions (iii) to (vi) see "Two Span Continuous Beams with Varying Span Ratios," by the author, *Concrete and Constructional Engineering*, August, 1923.)

We will assume the dimensions of our beam to be arbitrarily fixed at 36 in. depth to steel and 12 in. width, when it will be found that the arrangement of bars shown in *Fig.* 2 provides enough steel to take the tension. Actually the steel required is as follows :—

At support 2·98 sq. in. (7—$\frac{3}{4}\varphi$ give 3·09 sq. in.).
In long span 2·22 ,, (5—$\frac{3}{4}\varphi$,, 2·21 ,,)
In short span 1·02 ,, (5—$\frac{3}{4}\varphi$ actually used).

Having decided upon the arrangement of reinforcement, we next require to know the variations of I. In this connection it should be noted that horizontal bars only should be counted, since they are analogous to the chord members of a truss, and the bending moments are resisted by these chord members and not by the web members, which in our case are the bent-up rods and stirrups used to take up shear.

I is calculated in the usual manner, which needs no explanation, with the following results :—

Two bars top and two bars bottom $I = 60{,}100$ inch units.
,, ,, ,, four ,, ,, $I = 63{,}700$,, ,,
,, ,, ,, five ,, ,, $I = 65{,}400$,, ,,
,, ,, bottom seven ,, top $I = 68{,}800$,, ,,

These results are plotted in *Fig.* 3, from which it is seen that the variation of I cannot well be expressed by an algebraic expression, so that any mathematical treatment of this subject must necessarily be in the nature of an approximation.

The maximum variation of I is $\dfrac{68{,}800 - 60{,}100}{60{,}100} = 14{\cdot}5$ per cent.

The beam spans should then be divided into a convenient number of parts, say eight, and the following table prepared, in which

x	Ix inch units.	Mx inch lbs.	$\frac{Mx}{Ix}$	$\frac{xM_1}{L}$	$\frac{xM_1}{L.Ix}$
0	63,700	0	0	0	0
1	63,700	900,000	14·1	189,000	3·0
2	65,400	1,270,000	19·4	378,000	5·8
3	65,400	1,560,000	23·8	567,000	8·7
4	65,400	1,800,000	27·5	756,000	11·6
5	63,700	1,560,000	24·5	945,000	14·8
6	63,700	1,270,000	19·9	1,134,000	17·8
7	65,400	900,000	13·8	1,323,000	20·2
8	68,800	0	0	1,512,000	22·0
9	65,400	576,000	8·8	1,323,000	20·2
10	63,700	815,000	12·8	1,134,000	17·8
11	60,100	999,000	16·6	945,000	15·7
12	63,700	1,152,000	18·1	756,000	11·9
13	65,400	999,000	15·3	567,000	8·7
14	65,400	815,000	12·5	378,000	5·8
15	63,700	576,000	9·0	189,000	3·0
16	63,700	0	0	0	0

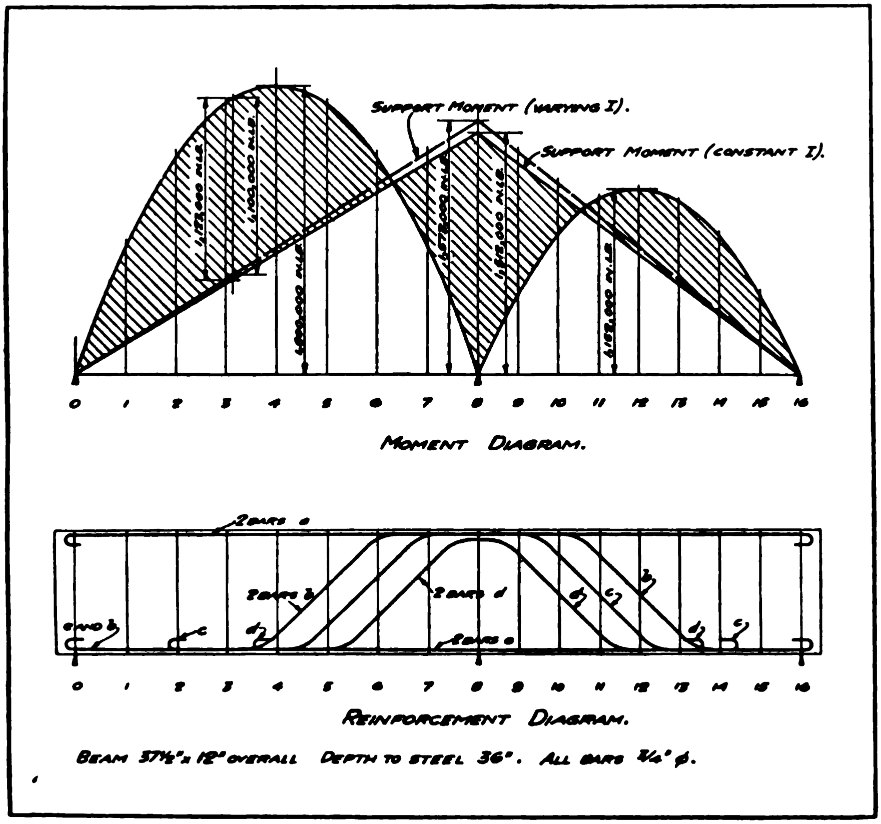


FIG. 2.

x = Section of beam under consideration.
Mx = Free bending moment at section x.
Ix = Moment of inertia at section x.
M_1 = Support bending moment.
$\frac{xM_1}{L}$ = Ordinate to support bending moment line at section x.
L = Span.

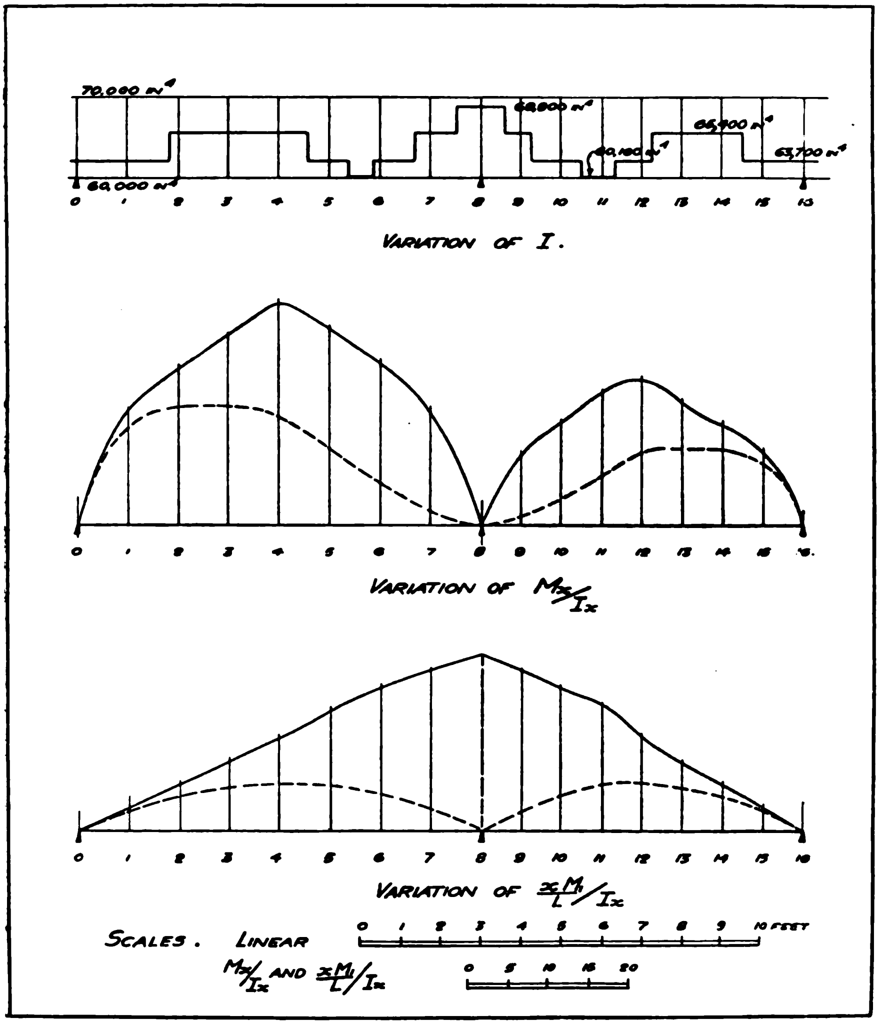


FIG. 3.

Curves should then be plotted giving the variation of $\frac{Mx}{Ix}$ and $\frac{xM_1}{L.Ix}$, and these are shown in *Fig.* 3.

Then if

L, L_1 are the respective spans,

a, a_1 the areas of the curves of $\frac{Mx}{Ix}$,

x, x_1 the distances of the centres of gravity of these curves from the outer supports,

A, A_1 the areas of the curves $\frac{xM_1}{L.Ix}$,

y, y_1 the distances of the centres of gravity of these curves from the outer supports,

the actual moment at the support will be β times the assumed moment as calculated, β being found from the equation

$$\frac{ax+\beta Ay}{L} = -\frac{a_1x_1+\beta A_1y_1}{L_1} \quad . \quad . \quad . \quad . \quad . \quad \text{(vii)}$$

The areas and positions of the centres of gravity can be found by any convenient means, but for this article were found by means of a planimeter, giving the following results :—

Span L	a	x	A	y
20 ft.	365·2	10·07	231·6	12·93
Span L	a_1	x_1	A_1	y_1
16 ft.	190·0	8·15.	185·6	10·37

The original curves from which the above figures were obtained were drawn to a scale of 4 ft. per in. linear and 10 units per in. for $\frac{Mx}{Ix}$ and $\frac{xM_1}{L.Ix}$. In the case of the curve for $\frac{Mx}{Ix}$ over span L the area enclosed by the curve was 9·13 sq. in. which multiplied by 40 gives 365·2. The positions for the centres of gravity were found by means of the derived curves drawn in chain lines in *Fig.* 3.

Substituting our values in equation (vii) we get

$$\frac{365{\cdot}2 \times 10{\cdot}07 + \beta \times 231{\cdot}6 \times 12{\cdot}93}{20} = -\frac{190 \times 8{\cdot}15 + \beta \times 185{\cdot}6 \times 10{\cdot}37}{16}$$

$$\therefore \frac{3678 + 2997\beta}{20} = -\frac{1549 + 1924\beta}{16}$$

$$\therefore 3678 + 2997\beta = -1936 - 2405\beta$$

$$\therefore 5402\beta = 5614 \qquad \therefore \beta = 1{\cdot}04 \text{ approx.}$$

(An increase of approximately 4 per cent.)

$\therefore$ Actual support moment
= 1,512,000 × 1·04
= 1,573,000 inch lbs.

Then the actual negative moment curves are drawn in *Fig.* 1.

The point of maximum positive moment in the longer span is approximately

·385 *L*, hence the increase of negative moment at that point will be ·015 approximately, or about 23,000 inch lbs., giving an actual positive moment of 1,100,000 inch lbs., a decrease of 2·1 per cent.

The reduction of positive moment in the shorter span is of course rather larger proportionately, being about 4 per cent.

The effect of the increase in support moment upon the position of the point of contraflexure is to move this towards the centre of the span, the greatest movement being in the shorter span and is about 2 per cent. of the span length.

From further figures in the possession of the author it would appear that the following are approximate average results for two span beams.

Variation of I. Per cent.	Variation in Support Moment. Per cent.	Variation in Positive Moment. Per cent.
+ 15	+ 5	— 3
+ 30	+ 11	— 6

The effect upon the position of the point of contraflexure does not appear to exceed a movement of 2 per cent. of the span towards the centre for general cases.

AMERICAN CEMENT MAKERS' VISIT.

UNDER the auspices of the British Cement Makers' Federation, a party of Delegates of the American Portland Cement Association paid a week's visit to England last month. Among the delegates were Messrs. F. W. Kelley (President, Helderberg Cement Co.); F. W. Kelley, Jnr.; John W. Boardman (Vice-President, Huron Portland Cement Co. and Wyandotte Portland Cement Co.); H. R. Browne (Michigan Alkali Co.); Morris Kind (President, Hercules Cement Corp.); D. A. Abrams (Structural Materials Research Laboratory); F. E. Tyler (President, Dewey Portland Cement Company); Wm. M. Kinney (General Manager, Portland Cement Assn.); A. C. Tagge (Vice-President, Canada Cement Co., Ltd.); Ernest Ashton (Lehigh Portland Cement Co.); R. P. Butchart (President, British Columbia Cement Co.); F. G. McKelvy (Vice-President, Alpha Portland Cement Co.); H. A. Schaffer (Portland Cement Association); S. W. Traylor (Representing New Egyptian Portland Cement Co.); J. C. Eden (President, Superior Portland Cement Co.).

During their stay in this country an inspection was made of the Associated Portland Cement Manufacturers' works at Stone, Greenhithe, and the Aberthaw and Bristol Channel Co.'s works at Aberthaw. On their way to Oxford, where a special visit had been arranged, part of the journey was made over the concrete section of the Great Western Road at Brentford.

On September 5 the visitors were specially conducted over the British Empire Exhibition. At a lunch given after the tour congratulatory remarks were made by the delegates on the remarkable achievement attained in the construction of the Exhibition, and it was also stated that the concrete buildings bore testimony to the vast possibilities of the use of concrete as a building material in England. The next day a visit was paid to the concrete cottages erected on the "Duo-Slab" system at Meanwood, Leeds, where keen interest was shown in the method of construction.

From Meanwood the party proceeded to Leeds for the unveiling of the tablet presented by the American Portland Cement Association (illustrated in our Frontispiece) to commemorate the centenary of the invention of Portland cement by Joseph Aspdin. The delegation were met by the Lord Mayor of Leeds and were accorded a civic reception. At the ceremony the British Cement Makers' Federation were represented by Messrs. P. M. Stewart (Chairman); F. T. Halford (Vice-Chairman); A. C. Critchley; G. F. Earle; L. Lister-Kaye; S. G. Robinson; E. A. Browne (Secretary); H. M. Brabant (Asst. Secretary).

THE LATE H. K. G. BAMBER.

LITTLE more than 60 years of age and still in the prime of life, Henry Kelway Gwyer Bamber passed away on Saturday, September 20th, as the result of a collision between a motor-car and a motor-cycle combination at cross roads on the newly re-constructed Watling Street near Gravesend. In company with his brother, Montague Kelway Bamber, and other friends, he had been shooting at Burham, on the Medway, and was on his way home at the time of the tragedy. Mr. Montague Bamber, who was staying with him at Stone Castle, near Greenhithe, was driving when the accident occurred. The car was overturned and all the occupants thrown out. Mr. H. K. G. Bamber was killed instantly, and his brother died in Gravesend Hospital a few hours later. Mr. Henry Bamber's name was a household word in the cement world of the United Kingdom, and Mr. Montague Bamber held the important post of Scientific Adviser to the Agricultural Department of the Ceylon Government, but was on furlough at the time.

THE LATE H. K. G. BAMBER.

Mr. Bamber was born at Pinner, on February 5th, 1864, and was the son of the late Henry Kelway Bamber, who for many years practised as an Analytical Chemist at 9 Victoria Street, Westminster. Educated at University College, Gower Street, W.C., and at the College of Mines in Kensington, he began his business career in his father's laboratory and there acquired a sound theoretical knowledge of the chemistry of cement manufacture. In 1887 he took an appointment as chemist at the cement works owned by J. R. Patrick & Son at Dovercourt, Harwich, and there acquired his first practical experience in the cement industry. He remained with them about seven years and later, in 1894, was invited to enter the service of Knight, Bevan & Sturge, cement manufacturers, of Northfleet, Kent, owners of the "Pyramid" brand which was so well known not only in the United Kingdom but also in the Colonies and the many foreign countries to which English Portland cement was then exported. It was not long before he became a junior partner in the firm, and so thoroughly had he won the confidence of his seniors that when the Associated Portland Cement Manufacturers, Ltd., was formed in 1900 by a combination of more than a score of the leading houses in the trade, his partners stipulated, when selling their business, that Mr. Bamber should receive a seat on its Board. When transferring the property to the Associated Portland Cement Manufacturers, Ltd., Mr. Bevan remarked that though the properties were very valuable he believed the greatest asset of all was Mr. Bamber himself. By his energy, enthusiasm, and ability Mr. Bamber justified this claim, and for 23 years was one of the small group of Managing Directors who controlled the fortunes of the combination, and during that time his attention was given to the technical side of the work. Upon the formation of the British Portland Cement Manufacturers, Ltd., in 1909, Mr. Bamber became one of the Managing Directors of that Company also and continued to hold both appointments until the end of 1923, when he relinquished the Managing Directorships but retained a seat on both Boards together with the position of Consultant.

But though primarily concerned with the manufacture of Portland cement and sharing in large degree the responsibility and the credit for the great advance which has been made during the past quarter of a century in the quality of British Portland cements, Mr. Bamber's activities were not confined to the manufacturing side alone. He was intensely interested in the development of concrete construction, and was one of the founders of the Concrete Institute in 1908, joining its Council in 1911, becoming Honorary Secretary in 1923 and Vice-President in 1924, the Institute having meantime changed its name and become the Institution of Structural Engineers. He took an active part in its affairs, served on several of its Committees, and, had he lived, would probably have become its next President.

Shortly after the formation of the British Engineering Standards Association, Mr. Bamber became a member of the Sub-Committee appointed to draft a Standard Specification for Portland Cement, and took a prominent part in framing it. He remained a member of this Sub-Committee until his death, and had devoted much time and energy to the revision of the Specification which is now in progress.

Mr. Bamber acted as Chairman of the first International Cement Congress held in London during the spring of this year and took an active part in its discussions. He was an Associate of the Institution of Civil Engineers, and a Fellow both of the Chemical Society and of the Society of Chemical Industry. He was appointed a Justice of the Peace for Kent in 1913, and took a keen interest in all movements connected with the social welfare of the locality where he resided, and especially in all that pertained to the well-being of the employees of the companies of which he was a Director.

Of Devonshire stock, though born in London, he had a remarkable affection for that beautiful county, and nothing pleased him better than a quiet holiday spent in fishing in some Devonshire stream. He married a Devonshire lady who, with five children, survives him.

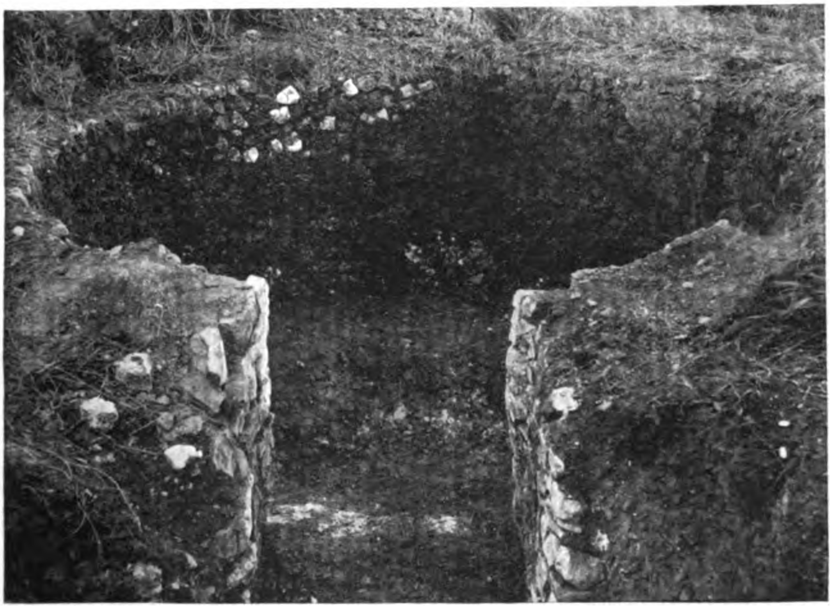
He was of a happy and genial nature, keen and enthusiastic in his work and in everything which aroused his sympathy, and he was universally popular; his tragically sudden death has created a gap which will not be easily filled. To those who shared with him the responsibilities and anxieties of a great business the personal loss is very heavy, and it is hard to realise that one who preserved in such unusual degree an almost youthful joy in life, together with a physical and mental vigour much above the average of men in his years, has passed into the Great Beyond.

THE CENTENARY OF PORTLAND CEMENT.*

It seldom falls to the lot of the reader who endeavours to keep up-to-date with the technical literature of his profession to come across a book which can be read with pleasure as well as with profit, but this is the good fortune of the reader of this volume. Probably few have realised the romance and mystery attaching to the early development of Portland cement, because this is the first attempt that has been made to produce a comprehensive history of the subject. Although the book is issued to commemorate the centenary of the invention of Portland cement, the reader soon discovers that the usual statement of the text-books that " Joseph Aspdin of Wakefield invented Portland cement in 1824 " can hardly be accepted without qualification. Much historical research was evidently needed to establish the true position, and with the aid of the original patents, which are given *in extenso*, it is possible to follow the clues indicated by the author, who seems inclined to regard Joseph Aspdin as the originator of the name " Portland cement " and nothing more.

Aspdin's patent covers the calcination of a mixture of lime and clay, but the degree of burning is apparently no more than that needed to produce lime, whereas Portland cement as now known requires to be burnt to the stage of incipient vitrifaction. Hence it may be said that Aspdin did not invent Portland cement at all, but only artificial hydraulic lime. Moreover, Vicat in France had already produced artificial hydraulic lime ten years before the date of Aspdin's patent; while, in England, Frost in 1822 had patented a " British " cement which was virtually a natural hydraulic lime and should have been identical with Aspdin's so-called Portland cement.

Therefore doubt arises as to the validity of Aspdin's claim for priority, even of the invention of artificial hydraulic lime. But it is still impossible to come to a definite conclusion because Aspdin kept his method of manufacture secret, and deliberately mystifying operations were practised in his factory, so that he may indeed have produced the semi-vitrified Portland cement without the knowledge



ROMAN LIMEKILN AT NORTHFLEET, KENT.

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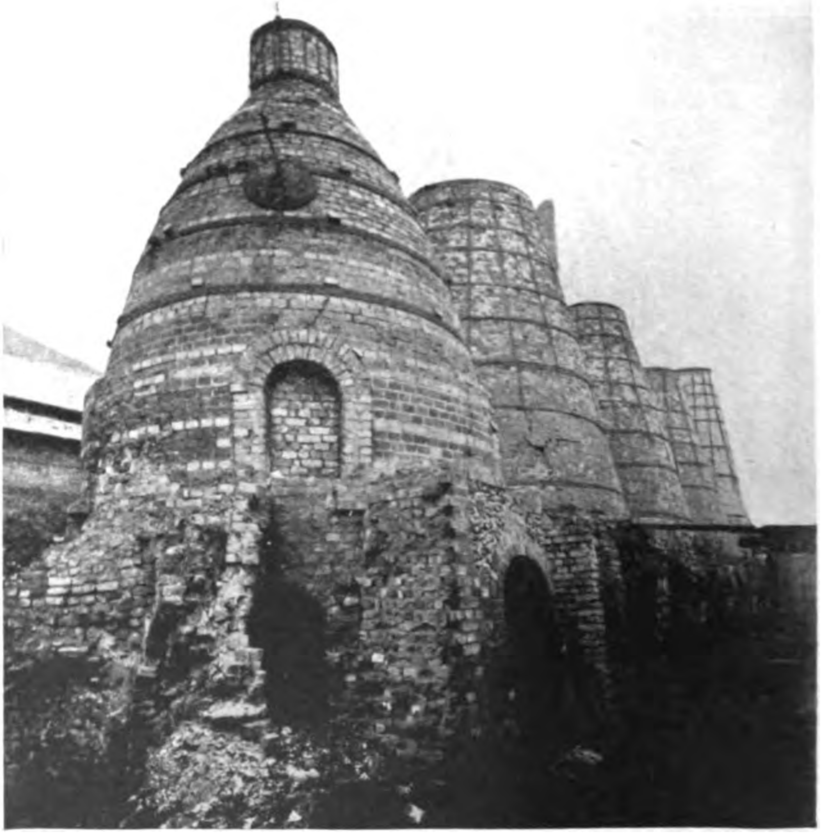
* "A Hundred Years of Portland Cement, 1824–1924." By A. C. Davis. (London: Concrete Publications, Ltd. pp. xxi. + 282. Price: Cloth bound, 21s.; Leather, 25s.)

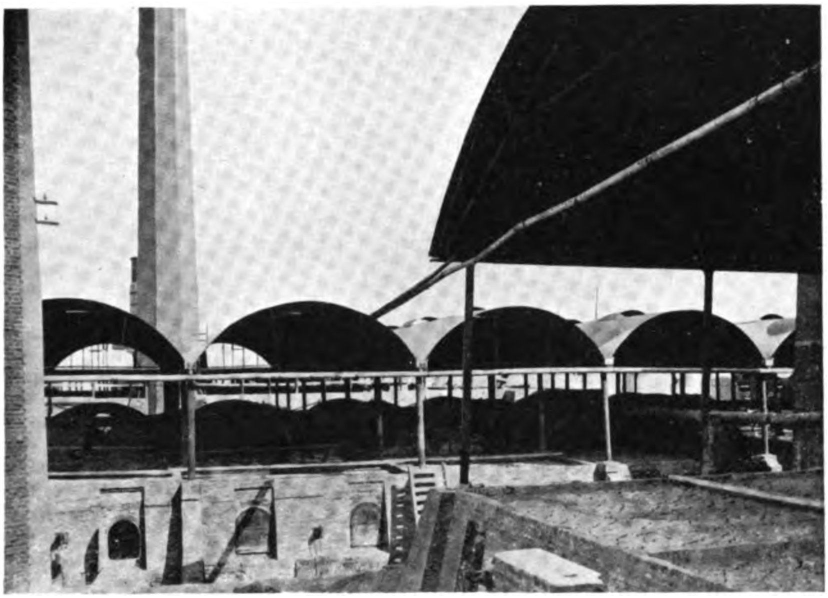
of his contemporaries. It follows therefore that the invention of the real Portland cement or the rediscovery of Aspdin's secret was made by another, and the evidence points to I. C. Johnson as being entitled to this honour. Johnson became connected with the cement industry in his youth and maintained a practical interest in the manufacture for the remainder of his long life of a hundred years. The account of Johnson's discovery of the true Portland cement is recorded in his own words and the story makes very interesting reading, especially in connection with the astounding episode of a London analyst's report that Aspdin's cement contained 45 per cent. of phosphate of lime. It is appropriate that the factory of Messrs. J. B. White at Swanscombe in Kent where Johnson made his discovery is now the largest cement works in the United Kingdom.

The author continues his historical survey of the industry from Aspdin's time until the present year, showing that for a quarter of a century the development of Portland cement was hindered by the competition of Roman cement, because in 1850 there were only four factories producing Portland cement. The Exhibition of 1851 and the interest taken in the cement by John Grant, Engineer to the Metropolitan Board of Works, a few years later served to popularise the material, and from this period Portland cement became firmly established as a constructional material. To Grant seems to be due the credit of putting the testing of cement on a scientific basis.

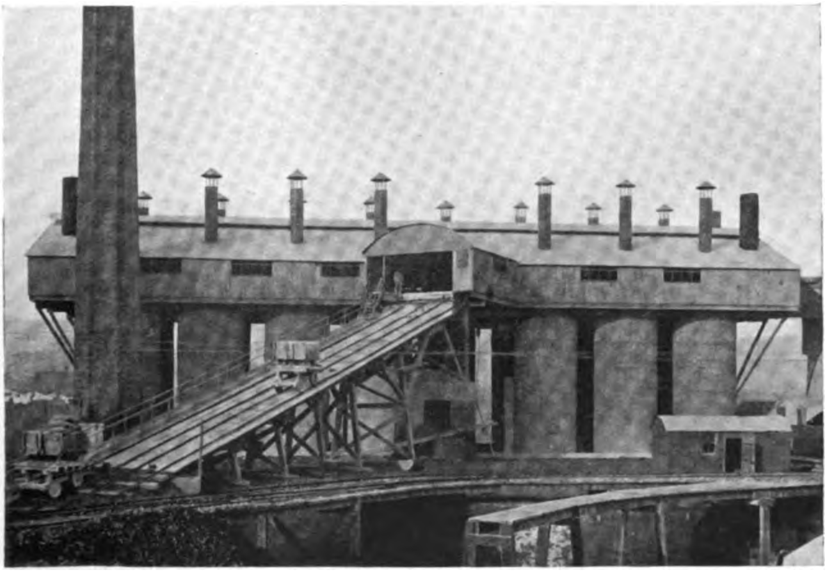
The technical progress of the industry can largely be traced in the improvement



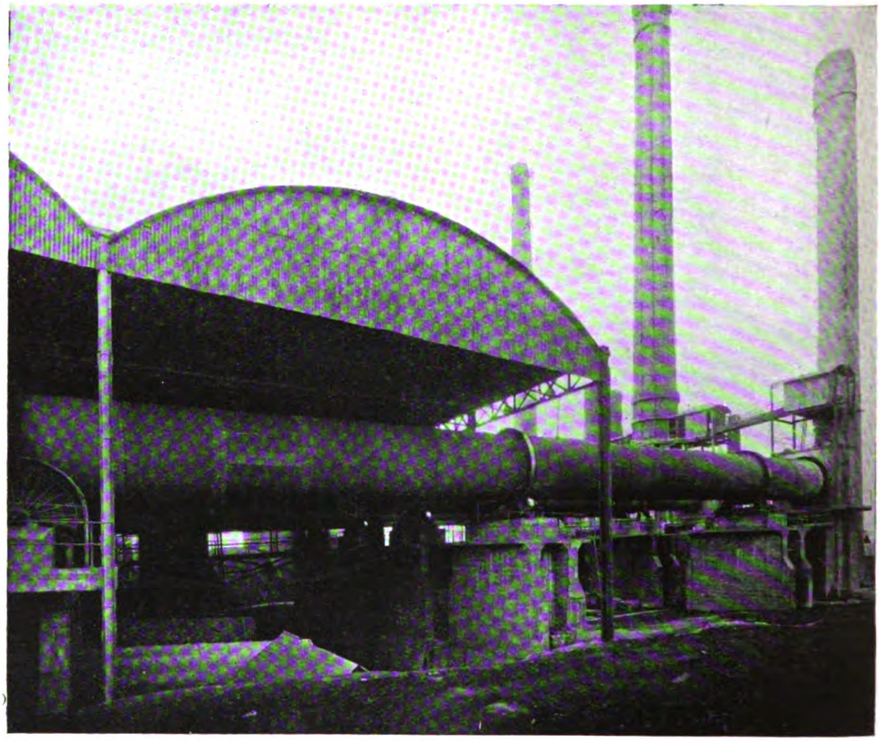
ROW OF ASPDIN KILNS AT MESSRS. ROBINS & ASPDIN'S WORKS AT NORTHFLEET, KENT.



DOUBLE SLURRY CHAMBER KILN.



BLOCK OF SHAFT KILNS.



MODERN ROTARY KILN PLANT, 1924.

of the kilns used for burning, and this the author does with descriptions and illustrations of the bottle kilns, chamber kilns, shaft kilns, and rotary kilns that have been successively used.

A chapter devoted to the development of the British Standard Specification for Portland cement serves to show the improvements that have been made in quality, and this feature is also strikingly illustrated by a graph showing the strengths of typical cements from Grant's time (1862) to the present day. A summary of the standard cement specifications of the world is of value for reference purposes, and a chapter on research in the cement industry conveys information, not previously published, of the work done by the British Portland Cement Research Association.

The book concludes with an appendix setting out in full some of the early patents for cement and the original patents of Crampton, Ransome, Stokes, Hurry, & Seaman for the rotary kiln.

Portland cement is of sufficient importance to warrant its history being written, and this volume, with the number of appropriate illustrations adding much to the interest of the book, is an exhaustive treatise on the various phases in the development of the material from the first beginnings when it was looked upon with a great deal of scepticism, through the period of growing improvement and popularity, until the production of the Portland cement which we know to-day. The book should be read by all engineers, architects, and builders who take an interest in the materials they use, and chemists and geologists will find much of interest in this account of the development of one of the most important industries in the world.

Our illustrations, which are taken from this book, show the types of kilns used throughout the history of cement manufacture.

SAUCER-SHAPE REINFORCED CONCRETE FLOOR BENEATH A THEATRE.

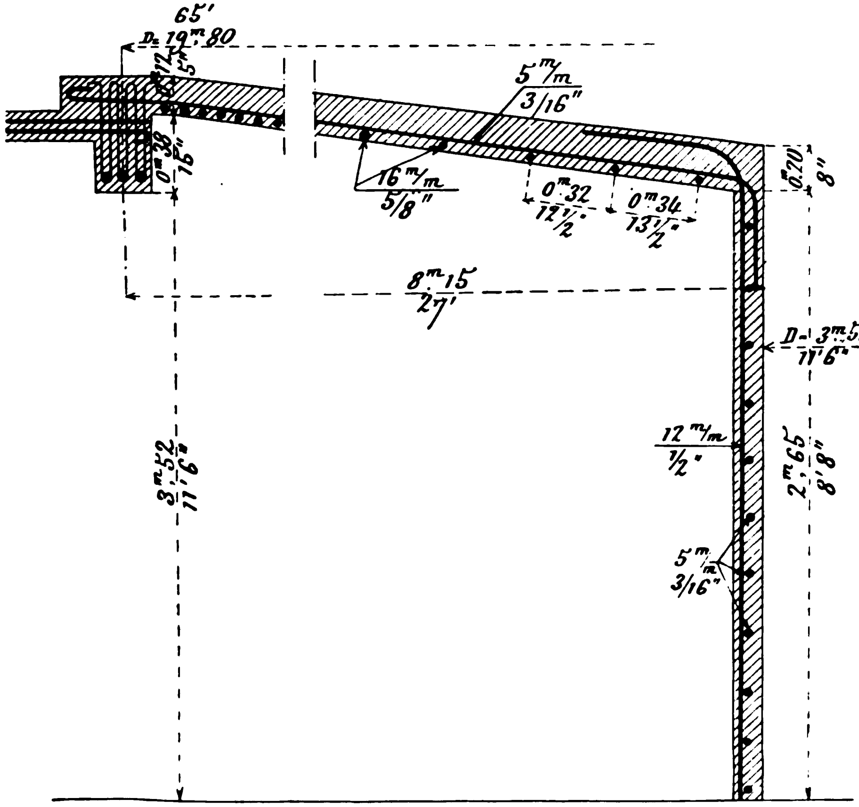
By PAUL CALFAS, Ing.E.C.P.

An interesting reinforced concrete floor has recently been built below the mechanism of a new revolving stage at the Grand Theatre, Lyons, and has provided space for a café beneath the stage.

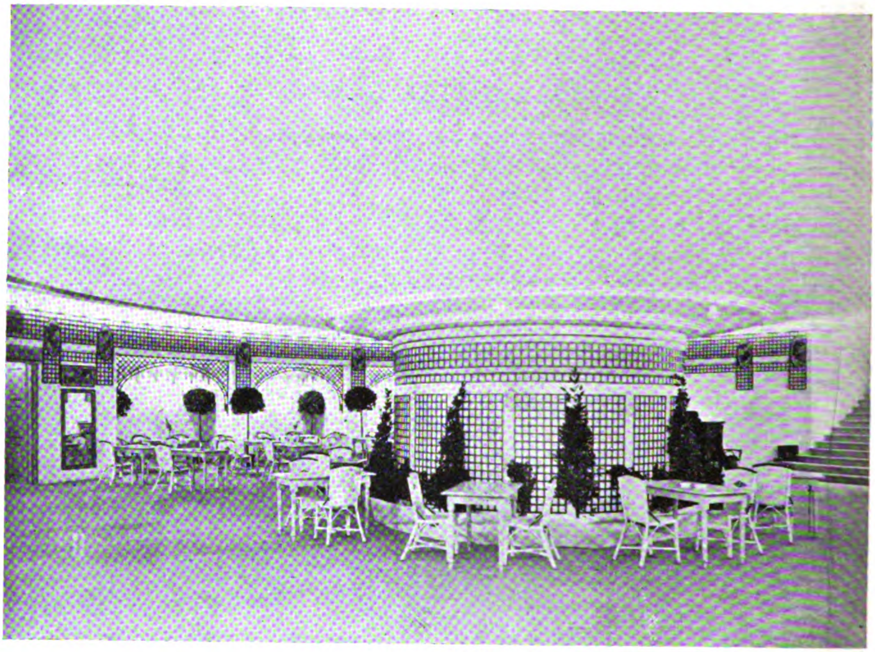
The floor is circular, about 65 ft. in diameter. In the centre the spindle on which the stage above revolves passes through the floor, and the new floor is supported at the centre by a circular reinforced concrete wall, 11 ft. 6 in. in diameter, surrounding the spindle and keeping it out of sight of those using the café. At its outer edge the new floor rests on a circular reinforced concrete beam which also serves as a travelling track for the rolling mechanism of the stage.

It was at first intended to construct a floor with radial and concentric girders, but this was abandoned, on the grounds of cost and appearance, in favour of the scheme as carried out.

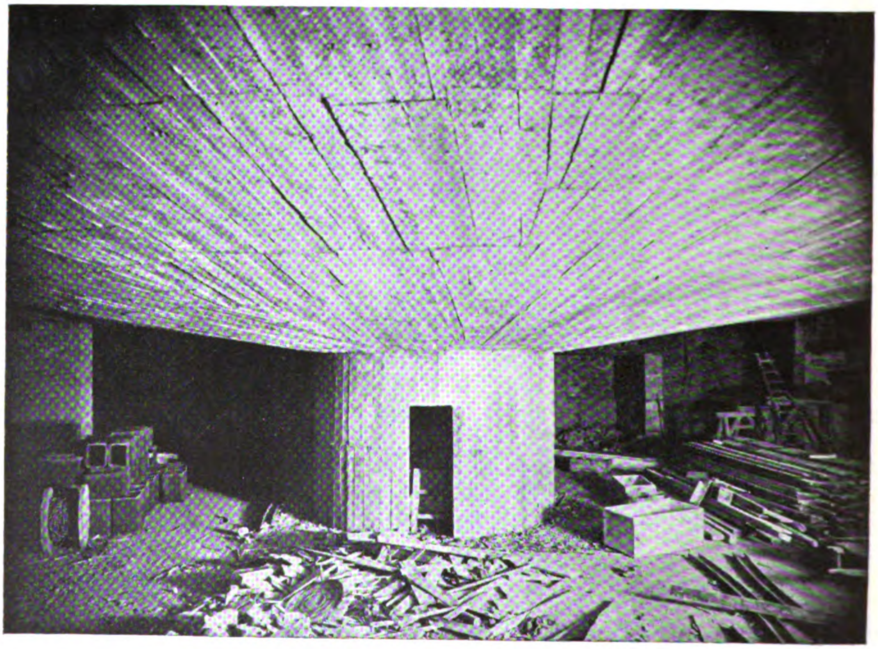
In designing the floor the general theory of flexible rotating surfaces was used, and the floor built of a minimum thickness. In order to reduce the weight,



Saucer-Shape Reinforced Concrete Floor beneath a Theatre : Half-Section.



THE CAFÉ COMPLETED.



DURING CONSTRUCTION.

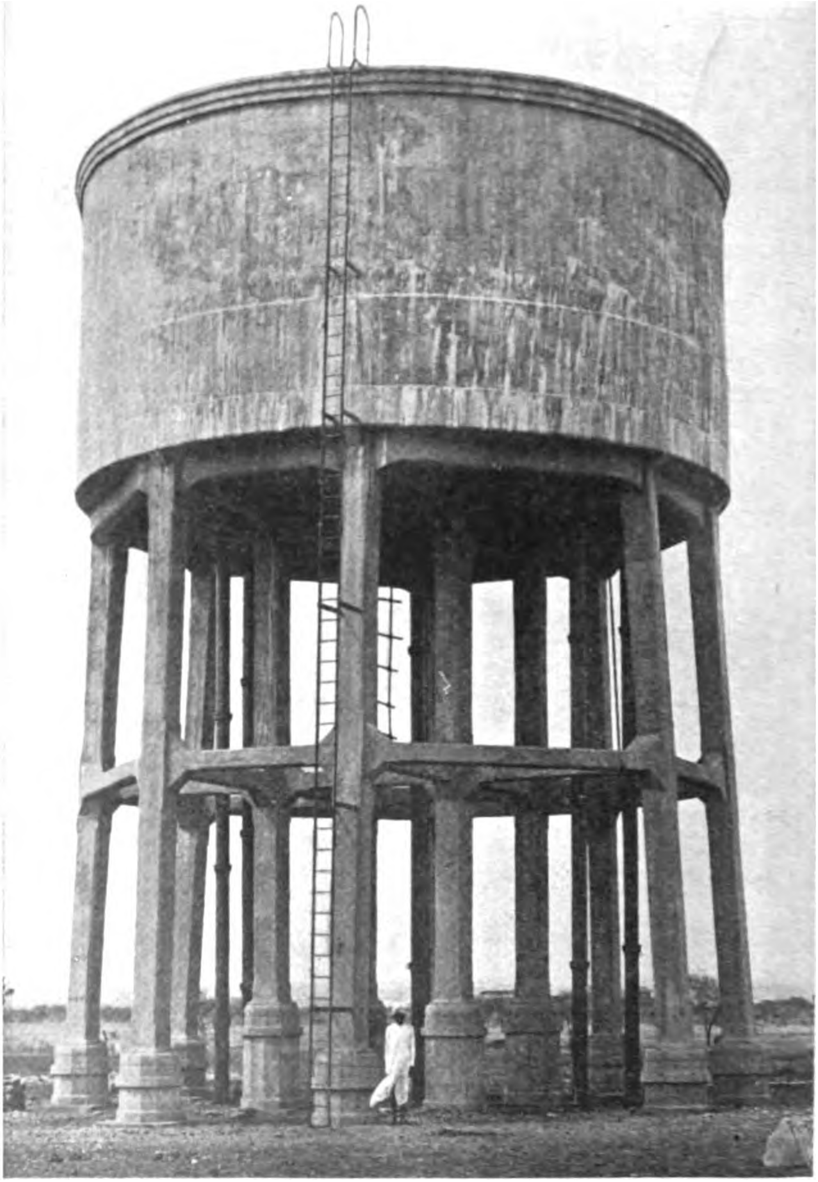
SAUCER-SHAPE REINFORCED CONCRETE FLOOR BENEATH A THEATRE.

and consequently the stresses on the reinforcing bars, slag was used as the aggregate in the proportion of 1 part quick-hardening cement to 8 parts slag. With the use of this mixture the maximum thickness of the floor was kept down to 8 in., while it was estimated that if a gravel concrete had been used it would have been necessary to make it 15 in. thick. The maximum thickness of 8 in. is at the centre, decreasing to 4¾ in. at the circumference. The total weight of reinforcement in the floor is only 8 tons.

The method of construction without girders enabled a considerable economy in formwork to be effected, and further to use as little timber as possible the floor was concreted in sections; after one section had set the formwork was rotated about the centre wall and placed ready for concreting the next section without lowering it from the level of the floor. Two timber frames were used, each extending over one-twelfth of the surface, and as the quick-hardening cement set in two days it was thus possible to concrete practically continuously.

The slag used for aggregate was free from coke and sulphur pyrites, and was sieved to two sizes, one between ¼ in. and $\frac{9}{16}$ in. and the other between $\frac{3}{32}$ in. and ¼ in.; these two sizes were mixed in the proportion of two parts of the smaller to one part of the larger.

It is estimated that the method of design and erection, and the use of slag for the aggregate, effected savings of 50 per cent. on the concrete, 55 per cent. on the weight of steel, and 40 per cent. in the time of erection.



REINFORCED CONCRETE WATER TOWER IN INDIA. (*See p.* 637.)

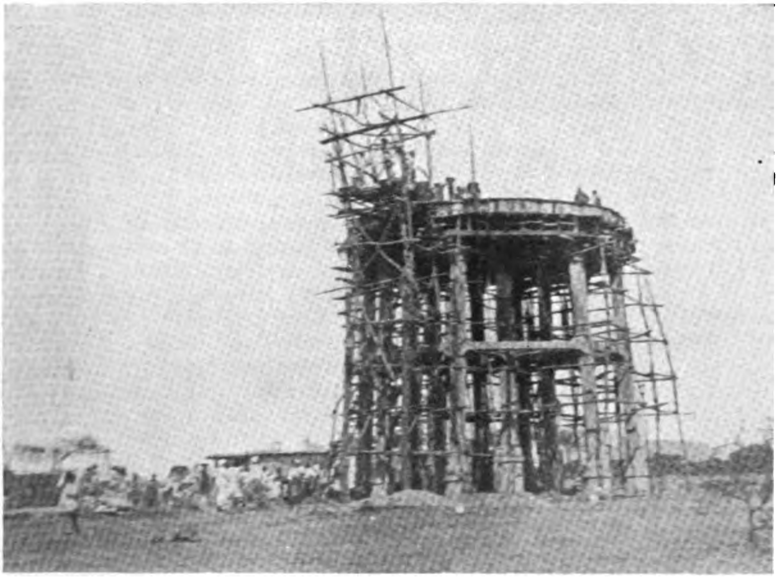
REINFORCED CONCRETE WATER TOWER IN INDIA.

INDIA is situated with the extensive areas of Asia on the north and the enormous expanse of the Indian Ocean on the south ; it follows therefore that when the Northern Hemisphere is turned towards the sun the whole of southern Asia becomes a super-heated region which draws towards it an immense current of air heavily charged with a water vapour picked up on its course over the ocean, and thus it is that parts of India are deluged with rain at one season of the year, while at other seasons no rain falls. The south-west monsoon is the most important, for upon it about five-sixths of the people of India depend. It spreads over the Arabian Sea and the Bay of Bengal and advances over India from these two seas.

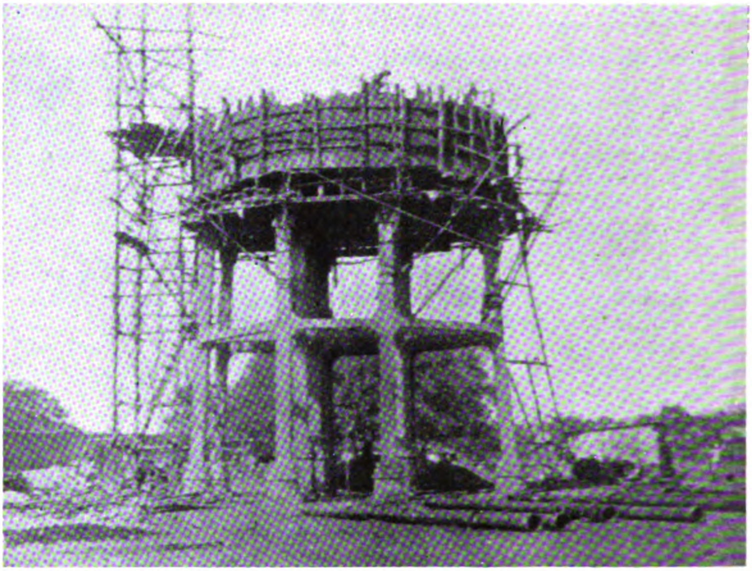
The monsoon period is from June to September, and the rainfall varies greatly. While the west coast gets about 100 inches the rainfall diminishes towards the centre and the east of the peninsula to about 20 inches, while south of Madras and in the Indus Valley it is only about 5 inches. It will thus be seen that the rainfall in different parts varies extensively, and while Bombay receives an annual normal fall of 70·68 inches, Poona which is situated to the south-east and is only about 75 miles away as the crow flies, only receives 27·11 inches owing to the Western Ghats which intervene.

With, generally speaking, eight months during which no rain falls, the question of supplying water for irrigation and domestic purposes becomes a problem which is constantly engaging the attention of the Government and municipalities, for water scarcity is a serious matter in the East and failure of the monsoon aggravates the situation. The general water supply for irrigation and domestic purposes is obtained from wells, but in many districts these run dry during the " hot weather " and the villagers have to travel miles to obtain water, while in some villages sweet water is not obtainable and has all to be carried from a distance. The principal cities have a water supply and mains laid, but the supply is by no means constant and the pressure in the mains low, and although the highest available land may be selected for the location of the reservoirs, it does not necessarily follow that the water will be available above ground level unless it is pumped up to an elevated tank.

The photographs reproduced show an elevated tank constructed at Yeravda, near Poona, which has recently been



REINFORCED CONCRETE WATER TOWER IN INDIA : DURING CONSTRUCTION.



Reinforced Concrete Water Tower in India: During Construction.

erected to supply the surrounding district with water.

Rock was met with a few feet below the surface, so no difficulty was experienced in the foundation work. The height to the bottom of the tank is 36 ft. There are four central straight supports 19 in. by 19 in., reinforced with eight $1\frac{1}{8}$-in. rods and $\frac{1}{4}$-in. binding; the eight outside inclined legs or supports, each 18 in. by 18 in., are reinforced with $\frac{7}{8}$-in. bars; the wind braces are $14\frac{1}{2}$ in. by $14\frac{1}{2}$ in. reinforced with four 1-in. bars and $\frac{1}{8}$-in. binding.

The depth of the water in the tank is 16 ft., the total capacity being 100,000 gallons, while the overall height is 53 ft. 6 in. from ground level.

At the bottom of the tank is a 9-in. thick slab, reinforced with $\frac{5}{8}$-in. round bars in both directions and supported on beams passing transversely and crosswise over the columns, the ends projecting beyond the columns being cantilevers, as can be seen in the photograph, while the slab is also designed as a cantilever where it projects beyond the edge of the beams.

The outside walls are 8 in. thick for a height of 5 ft. 6 in., above which they are 6 in. thick. The roof of the tank, which is supported on columns and beams (in a similar manner to the floor slab), is 4 in. thick. The reservoir is divided into two compartments to facilitate cleansing. The internal diameter is 36 ft.

The mixture used was 4 parts of crushed stone, 2 parts sand and 1 part cement for all members not in contact with the water; but for the floor and shell a $3 : 1\frac{1}{2} : 1$ mix was used. All materials were carefully measured, and special attention was paid to the measuring of the water required for the mix. No plaster work of any sort was done, the concrete being left just as it came from the moulds; even a cement wash on completion was dispensed with.

The moulded bases were cast *in situ* in teakwood moulds, which produced sharp arrises requiring no touching up. The whole of the shuttering throughout the job was planed on all surfaces against which the concrete abutted. The centering forming the shell was similarly treated.

After completion the tank was tested for watertightness and proved to be perfectly watertight. At the end of twenty-four hours it was found that the drop in the level of the water was only $\frac{5}{16}$ in. due to absorption by the green concrete, but no dampness or "sweating" has appeared anywhere.

The work was designed and executed by the Mawson Vernon Co., Ltd., of Souter Street, Bombay, for the Bombay Government.

DESIGN OF FORMWORK FOR REINFORCED CONCRETE CONSTRUCTION.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

II.—MATERIALS, LOADS, PRESSURES AND STRESSES

Timber

THE most easily obtainable timber for form work is pine, either Norway or American Southern pine, which is available in all sizes and is easily worked and cheap in comparison with other woods. Where strength is required, particularly in the larger size timbers, there is no wood equal to American pitch pine or Southern long leaf pine.

When it can be obtained spruce is one of the best timbers for all-round use. Hemlock is not desirable, as it is coarse grained and liable to curl.

Fir is now being used to some extent in America, and Douglas fir timbers are almost equal to long leaf pine.

Freedom from knots and coarse grain is desirable, as these will show on the finished concrete, for which reason soft white pine is one of the best timbers to use for mouldings, cornices, bridge parapet walls, etc., where an extra smooth finish is required. Soft white pine is, however, too expensive and has too little strength for form timber generally.

Hardwoods are not used for formwork except as caps and wedges under or over posts, where they are used to increase the allowable compression across the grain and so often allow a smaller post to be used. Hardwoods are difficult to work and nail.

Partially seasoned timber is the best for formwork, as if it is too dry it will tend to swell from absorption of moisture, while green lumber will tend to dry out and shrink in hot weather, causing fins and ridges on the concrete.

Timber may be rough or dressed, though workmen do not like to use rough wood. It may be dressed in various ways, such as all four sides, one side and one edge, one side and two edges, etc. Usually it is best to use timber dressed on all four sides, as it will then be of more uniform size and is more easily adaptable for different purposes.

Wood of any one size should be dressed to a uniform thickness, so that the pieces will match up ; this is particularly important with sheathing, as otherwise labour will have to be spent in planing down the joints. Joists and studs, too, if they are not of uniform thickness, will cause considerable trouble in fitting.

Sheathing, 1 in. to 2 in. thick, may be tongued-and-grooved, square, or bevelled edge. Tongued-and-grooved gives the best results, while a bevelled edge is good if the wood is very dry, as when built up it will not buckle so easily when swelling. Square-edged timber is usually only used in the heavier thicknesses.

Thicknesses of timber will depend on the available supply and the loads to be carried, but more often on the former, as any ordinary size can be used to advantage by adjusting the spacing of the supports.

In general, for floor sheathing, 1 in. dressed down to $\frac{13}{16}$ in. is the usual practice; for wall sheathing and beam and column sides the thickness may vary from 1 in. to 2 in. stock dressed $\frac{3}{16}$ in. or $\frac{1}{4}$ in. Beam bottoms are generally 2 in. stock.

Joists may be any size from 2 in. by 4 in. to 3 in. by 10 in., 2 in. by 6 in. being the commonest size; column yokes are usually 3 in. or 4 in. by 4 in.

Studs and wales vary from 2 in. by 4 in. to 6 in. by 6 in.; posts from 3 in. by 4 in. to 6 in. by 6 in.

In ordinary work the smaller sizes mentioned above are used, extra strength being obtained by doubling up.

The lengths of timber ordered, when this can be specified, should be such that they can be used to the best advantage, with the least waste, a point which is often overlooked.

Sheathing can be ordered in random lengths, as it generally has to be cut up and short lengths can always be worked in.

Joists, studs, posts, beam bottoms, etc., where exact dimensions have to be met, should be ordered the nearest commercial length to the height or span required. If floor joists, for instance, are to span 5 ft. 6 in. they should be ordered in 12-ft. lengths for the least waste. Care in specifying the lengths is important, otherwise there will be a lot of short ends and a surprising percentage of waste. Timber cost is a big item in reinforced concrete construction, and it should be ordered and used with care.

Nails

Common wire-cut steel nails are used, the most general sizes being 6*d*., 8*d*., 10*d*. and 20*d*.

Double-headed nails, if they can be obtained at a reasonable price, are an advantage as they can be drawn easily.

Wire and Bolts

Tie wire for tying wall forms may be either number 8, 9 or 10 black annealed wire, number 9 giving the best service for ordinary work.

Steel or galvanised iron wire should not be used, as it is brittle, hard to handle, and too springy.

Bolts with washers and nuts are generally used in heavier wall construction in sizes from $\frac{1}{2}$ in. to $\frac{3}{4}$ in., usually with square heads and nuts. If they are to be drawn after use they should be well greased or fitted with sleeves.

Oil or Grease

All forms coming in contact with the concrete, if the concrete is not to be plastered, should be well oiled or greased to allow easy stripping and to prevent concrete adhering to and coming away with the forms.

If the concrete is to be plastered the plaster will adhere better if the surface is rough.

Special non-staining oil, made for the purpose, is the best to use, though soft soap and water is satisfactory.

Patented Articles

There are many patent devices for facilitating the erection and stripping of forms, such as clamps, column yokes, adjustable shores, etc. Most of these are satisfactory and will save time and labour on a large job, but taking into account their first cost and the fact that they are easily lost, the ordinary methods are sometimes the cheapest in the end. Some of these special devices will be mentioned later.

Loads

The load to be carried by formwork is the weight of the wet concrete and the forms themselves and a live load which allows for impact, wheeling over the forms, etc., and is therefore a construction load.

The weight of the forms can be neglected, as it is small compared with the other loads.

To simplify calculations, the weight of concrete may be taken as 144 lbs. per cubic foot. It is then only necessary to multiply the thickness of a floor by 12 to get the weight per square foot, or to multiply the depth and width of a beam together to get the weight per lineal foot.

For instance, a 5-in. slab will weigh 60 lbs. per sq. ft., and a beam 10 in. wide by 18 in. deep will weigh 180 lbs. per lineal foot. Inclined slabs, such as often occur in power-house floors and saw-tooth roofs, will cause an overturning movement to the top of the posts, and this must be taken care of by adequate bracing.

The assumed construction live load is generally taken as 75 lbs. per sq. ft. of floor. This value should always be used in designing floor sheathing and joists; but when calculating the deflection of joists it can be reduced to 40 lbs. per sq. ft., as it will only exist during concreting and then only for short periods. After a bay is concreted there will only be the dead load to be carried, and 40 lbs. per sq. ft. will allow for any accidental loading.

Live load on ledgers is often omitted when calculating deflection.

For the good of both the concrete and the forms, the piling of timber, steel, cement, etc., on freshly-poured concrete should not be allowed. If it is known beforehand that, owing to confined space, some material must be placed on the concrete the day after it is poured, then the forms should be made extra stiff and should be designed to carry this loading with a small deflection.

Pressures

In vertical sections, such as columns and walls, a horizontal pressure will act on the forms due to the hydrostatic head of the wet concrete. This is the pressure which causes most of the bulges and collapse of forms.

It is a much debated point what pressures should be allowed for in the form design, and it is a subject about which there is as yet not much definite information. The pressure will depend on the rate of filling and the temperature.

The faster the forms are filled, and also the lower the temperature, the greater will be the pressure, because the concrete does not set so quickly and thus relieve the pressure. If a wall were poured so slowly that each layer set before the next layer were poured, when the wall was full the pressure at the bottom would be no greater than at the top. This is the principle of moving forms with which elevators and bins of all kinds and sometimes walls are built. The form is raised at about the same rate as the concrete sets, so that each layer supports the layer above.

Concrete at a low temperature will set slowly, and for a given rate of pouring the pressure may be 50 to 75 per cent. greater than when the temperature is twice as high. For this reason forms should be built stronger in very cold weather than in the summer, and not stripped so soon.

Temperature considerations are, however, not often taken into account in designing forms, except in very cold weather, and the pressure is assumed at an average temperature allowing an ample factor of safety.

Rate of pouring is more important, and must be taken into account. Many wall and column failures have occurred by pouring concrete too fast, or, if it was necessary to pour fast, by designing the forms too weak. If a 1-cu. yd. mixer is used, naturally the wall will be filled faster than if a ½-cu. yd. mixer is used, and hence the forms must be made correspondingly stronger.

Vertical sections should always be poured as slowly as is consistent with economy, and in long layers about 12 in. thick.

Concrete in heavy walls and piers, in which large stones or " plums " can be embedded, will always exert less pressure on the forms than when the stones are omitted, because true hydrostatic pressure will not exist.

Since the outward pressure depends mainly on the rate of pouring, column sides will be under greater pressure than wall sides, since they are filled faster. Column forms, however, should never be filled to the top without a break ; instead, each batch of concrete should be distributed amongst several columns. For column forms a hydrostatic pressure equivalent to that due to a liquid weighing 125 lbs. per cu. ft. should be used ; that is, the pressure on any yoke per lineal foot will be the depth from the top multiplied by 125 multiplied by the spacing apart of the yokes.

Small low walls may be poured as fast as columns and the same pressure should be used, but the higher and wider the wall the slower will it be filled and the pressure exerted at any point will correspondingly decrease.

With ordinary thicknesses of walls it is simpler, for calculation purposes, to consider the height of the wall instead of the rate of pouring, the one being proportional to the other. The width does not affect the pressure, but does influence the speed of pouring, so that thin walls should be poured more slowly than thick walls, assuming that they are not designed for fast pouring. To some extent in narrow walls friction and arch action reduce the hydrostatic pressure.

The following is a useful guide to follow in designing ordinary walls in order to be on the safe side.

Height of wall.	Pressure will be equivalent to that of a liquid weighing
Less than 5 ft.	145 lbs. per cu. ft.
,, ,, 5 ft. to 10 ft.	125 ,, ,, ,,
,, ,, 10 ft. to 20 ft.	100 ,, ,, ,,
Over 20 ft.	75 ,, ,, ,,

The consistency of the concrete also affects the pressure, increasing with the increase of the percentage of water in the mix.

Stresses

As formwork is only temporary, higher unit stresses may be allowed than would be permissible in permanent work.

For yellow pine, spruce, fir, and timbers of equal strength a maximum fibre stress of 1,200 to 1,400 lbs. per sq. in. for bending may be used, the former value being the most common and is conservative. For horizontal shear 200 lbs. per sq. in. should be used, and for bearing or crushing across the grain 400 lbs. per sq. in.

For American long leaf or pitch pine these stresses may safely be increased by 50 per cent.

For posts with square end bearing the maximum allowable compressive stress should be 1,000 lbs. per sq. in., to be reduced according to the ratio of the height or unsupported length to the least diameter by the formula

$$\text{safe unit stress} = 1{,}000\ (1 - h/80d),$$

where h is the unsupported length and d the least dimension of the cross-section.

For ordinary conditions this gives a unit stress of about 750 to 800 lbs. per sq. in., which is twice that allowable for compression across the grain. Therefore the size of posts will generally be limited by compression across the grain in the timbers they carry.

If oak or other hardwood caps or wedges are inserted between the load-carrying member and the top of the cap, the allowable unit compressive stress across the grain may be increased 50 per cent.

Modulus of Elasticity

For the purpose of calculating deflections the modulus of elasticity may be assumed at 1,200,000 lbs. per sq. in., which is the value commonly used for pine.

Deflection

In addition to strength in bending and shear, form members must be designed so that a safe maximum deflection will not be exceeded.

This may be taken at ⅛ in. for sheathing, using the full live load of 75 lbs. per sq. ft. For joists and beams carrying joists the deflection should not exceed ⅛ in. for dead load and a live load of 40 lbs. per sq. ft. For members under horizontal pressure, deflection should not exceed ⅛ in.

Deflection considerations will generally govern the thickness of sheathing.

Actual and Nominal Timber Sizes

It must be carefully noted that the actual dimensions of dressed wood will be less than the nominal by an amount varying from ⅛ in. to ½ in. This must be allowed for in design, as it makes a considerable difference to the strength of a timber, especially in the small sizes.

If the dressed sizes are not specified when ordering the following allowances should be deducted:

> For sheathing up to 2 in. in thickness, deduct 3/16 in. from the nominal thickness;
>
> For timbers 2 in. by 4 in. up to 6 in. by 6 in., deduct ¼ in. from each dimension;
>
> For timbers larger than 6 in. by 6 in., deduct ½ in. from each dimension.

This rule will be followed in all tables and calculations, as it will give safe values for either dressed or undressed timber.

Accuracy

Too great a refinement in design is not necessary, and is a waste of time. Exact calculations of bending moment are useless when so many assumptions are made as to live loads, stresses, quality of material, and especially workmanship on the job, and approximations are sufficiently close.

Sizes should be chosen that are sufficiently strong, remembering that actual construction in the field will not be as accurate as office calculations.

To design formwork intelligently a knowledge of the loads and pressures caused by wet concrete and the safe allowable stresses on timber is necessary, together with some knowledge of mechanics so that correct sizes can be chosen.

For those, however, who have had no training in mechanics, tables will be given covering ordinary conditions, from which the correct sizes to use can be obtained to suit the particular conditions.

QUESTIONS AND ANSWERS RELATING TO REINFORCED CONCRETE.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—*Ed.**

CONCRETE FLOORS.

Question,—I am faced with the work of putting in solid floors to a pair of cottages. The amount of space to be filled, i.e. between ground level and floor level, is in some parts 4 ft., and filling stuff is hard to obtain. Bearing in mind the fact that after filling in up to, say, 6 in. from finished floor for woodblocks and 5 in. for tiles, a 4-in. layer of 4 : 2 : 1 concrete is required for bedding tiles thereon, and ditto plus a 1-in. topping for blocks. I have thought that solid reinforced beams or joists, pre-cast and afterwards placed in position on proper beam supports or sleeper walls would be a better and cheaper job. Do you agree ? And if so can you please advise as to the necessary reinforcement for joists, say, 7 in. deep? The greatest span would be, say, 6 ft., the joists being cast in 6 ft. 6 in. lengths and ends butted on a supported beam below.

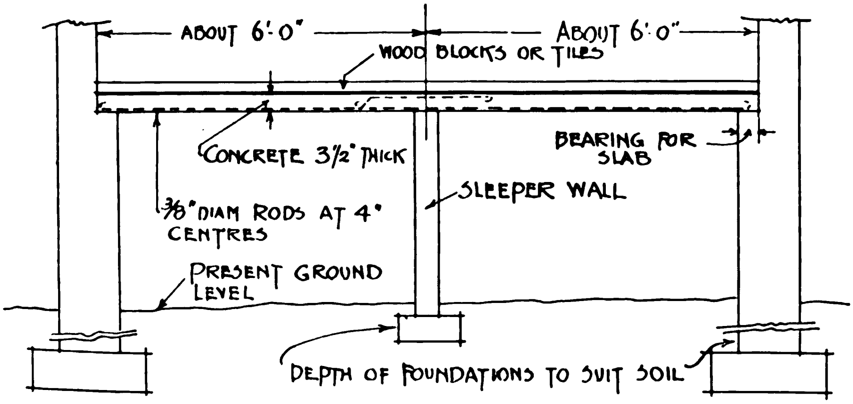
How wide would you make these joists if the space to be covered measured, say, 12 ft. Could they be made hollow with advantage, and can you advise me as to the cheapest method of producing them hollow ? I have hard waste brick (which I can crush to pass ½-in. ring) pit gravel washings from lead mines, etc.

If the foregoing does not appeal to you, can you advise an alternative ?—A.E.R.

Answer.—The suggestion to put in pre-cast concrete beams in lieu of filling does not appear to be economical or necessary. A better method to adopt would be that of forming a reinforced concrete slab over the whole floor *in situ*.

The thickness of concrete required is only 3½ ins., and if pre-cast units are used these would require to be reinforced with two ⅜-in. diameter rods in a width of 8 in. Each unit would weigh about 190 lbs., and would therefore be awkward to handle and the risk of damage, necessity for delay during maturing of the units, and difficulty of bedding accurately on the walls are serious disadvantages compared with the alternative method.

A sketch showing the alternate suggestion is given, but this must not be taken as a complete working drawing but merely as a guide to illustrate the method. The slab is 3½ in. total thickness, and the reinforcement consists of ⅜-in. diameter rods at 4-in. centres. The rods will require to be about 7 ft. 6 in. long to allow for hooks at the ends, and for carrying into the adjoining bay. Alternate rods should be cranked up as indicated and carried about 1 ft. 3 in. beyond the sleeper wall to prevent cracks in the upper surface at this point. Small diameter rods, say ¼ in. or less, should



be provided at right angles to the ⅜-in. rods at intervals of 2 ft., also to prevent temperature cracks. The sleeper wall can be built honeycomb if openings are required for ventilation, and support for the ends of the slabs can be provided by 4½ in. offsets, as shown. The concrete should be composed of 4 parts good clean hard broken material, 2 parts clean sand, and 1 part of Portland cement. Some simple shuttering will be required during concreting, and if there is any particular difficulty in getting out timber owing to the position of the work some old corrugated iron sheets could be used, and these could be left in permanently. Should any difficulty be experienced with regard to the rod reinforcement it would be quite satisfactory to use one of the many fabric reinforcements which are on the market. The concrete can either be screeded off and roughly floated ready to take the blocks or it can be left with a spade finish and a cement and sand screeding coat laid to give a level bed.

With regard to the question of making hollow beams this would not be practical, as collapsible cores are required, and the initial outlay would be prohibitive for a small job of this kind.

Either of the two machines mentioned by the querist should prove a good investment as machine mixed concrete is better than hand mixed material, and the saving in labour with the machine will quickly repay the initial outlay.—ALBERT LAKEMAN.

BOOK REVIEW.

Elementary Principles of Reinforced Concrete Construction. By Ewart S. Andrews, B.Sc., A.M.Inst.C.E. Third Revised Edition.
[London : Scott, Greenwood & Son. Price 7*s.* 6*d.* net.]

THIS edition does not differ very radically from its two predecessors. It may be said at once that it is wonderful value for the money, and does both author and publisher great credit.

The author adopts the standard notation, but has (we think wisely) refrained from following the several radical revisions which ill befit a standard, and do much to militate against its usefulness, however desirable in themselves the revisions might be ; it is unusual to give the notation a chapter number. Chapter III is a short but good introduction to the properties of the component materials. After this, the book becomes frankly mathematical in form and material. In so far as it professes to be for the use of students, engineers, architects, and builders, this is perhaps unfortunate, particularly from the point of view of architects and builders, who do not as a rule show any remarkable excitement in the presence of formulæ and diagrams. Whether the elementary principles can be explained in less mathematical language may be arguable, though we think that to a point they can be and have been, and to this extent have interested a much greater public than that which has sufficiently mastered mathematics to follow the author's treatment. We admit, of course, that to any one who is facile with mathematical treatment (as every engineer and designer should be) the mathematical treatment is at once the quickest and the most reliable. For these reasons, we should have thought its usefulness better described as for students and engineers. Even so, the work stresses the mathematical or design aspect unduly, to the exclusion of materials, methods of construction, fire resistance, resistance to corrosion, form work, etc., which surely should have considerable place in a book called " Reinforced Concrete Construction." We should prefer a title of " Reinforced Concrete Design " or " Reinforced Concrete Calculations " for the present work as more descriptive of its contents.

With this comment, the treatment is of the usual high standard which we have learned to expect of the author. Minor comments might perhaps include the following. Fig. 4 on p. 14 should have the curves drawn through the points, as the actual curves drawn by no means represent the results of the experiments referred to, and the fact that increase of strength with age is not a smooth regular curve might be pointed out. On p. 15 it is stated that a strength of 2,400 lbs. □" in 28 days is required for the working stresses in this book (600 lbs. □"). This we think excessive, and should be 1,600 lbs. □" in 28 days or 2,400 lbs. □" in three months.

The statement on p. 44 that " the principle of replacing the steel by m times its area of concrete is one which applies to all forms of reinforced concrete" is too wide, and clearly is not true in tension or shear, or when the elastic limit is exceeded. The graphical method of calculating stresses in reinforced concrete beams (given in Chapter IX) is interesting, but not to be recommended except in quite exceptional circumstances.

We think the author would have been well advised to insist that any arrangement of rods is good or bad just in so far as the theoretical requirements have been met by an arrangement which is also practically convenient. Some of the arrangements illustrated leave much to be desired.

After Chapter XII are questions in figuring of beams and stanchions with answers, which are of obvious use to students.

The remaining third of the book gives the L.C.C. regulations and mathematical tables.

O. F.

IRON OXIDE CEMENTS.

Many unsuccessful attempts have been made to use low grade iron ores for the manufacture of a kind of Portland cement which should be superior to that corresponding to the usual standard specifications. As iron oxide resembles alumina in many ways its difference in the case of cements seemed to call for some explanation, and the subject has recently been investigated by Dr. Hans Kühl.

It was then found, states *Zement*, that when iron oxide, silica, and marble of ordinary fineness are burned to form a clinker the product is unstable and useless, because the power which the substances have of reacting with each other is much too low! By using very pure materials (to eliminate chance errors due to impurities) and by grinding them before burning so that they passed completely through a sieve with 175 holes per linear inch good clinkers were obtained. The fuel consumption was the same as for Portland cement clinker, except in those mixtures which contained an unusually high proportion of silica and a very low proportion of iron oxide, for which more fuel was needed than for Portland cement. The resulting clinkers were well burned, very hard, and of a dark colour; those richest in iron oxide were almost black. On keeping the 46 clinkers produced, only those disintegrated which contained a large proportion of dicalcium silicate, owing to their being very deficient in lime.

Under the microscope a clinker corresponding in composition to Portland cement and containing 20 per cent. of iron oxide, 16 per cent. of silica, and 60 per cent. of lime consisted of a dark ground mass in which clear colourless crystals of high refraction were embedded. The ground mass appears to be a heterogeneous glassy mass—a sort of hotchpotch of surplus materials and consisting of a eutectic of iron oxide with the other constituents of the clinker; the crystals are the essential material and appear to be tricalcium silicate (alite) exactly as in Portland cement.

Clinkers of various compositions were mixed with 2 per cent. of gypsum and ground to the fineness of cement. Most of the products are slow in setting, but one sets rapidly. There appears to be no connection between the time of setting and the chemical composition, but an excess of lime destroys durability.

Under favourable conditions alumina-free cements can be obtained which are as strong as the best Portland cements, and show a good tensile strength after 3 days, but they must contain sufficient iron and more silica than Portland cement, because iron oxide (unlike alumina) does not produce cementitious compounds with lime.

On plotting the limits of composition of ferruginous cements on a triangular diagram, the former are located in an oval almost concentric with, but somewhat larger than, the corresponding field for Portland cements, the difference in the sizes of the two fields being due to the higher proportion of silica required by alumina-free cements. The precise nature of the essential minerals in the clinker was not proved, but whilst a good cement of this type need not actually consist of a mixture of tricalcium silicate, tricalcium aluminate, and tricalcium diferrate, these appear to be substances which build up the final clinker—possibly by the formation of double compounds of these units.

Whether it would be profitable to produce ferruginous cements of this character on a large scale remains to be seen.

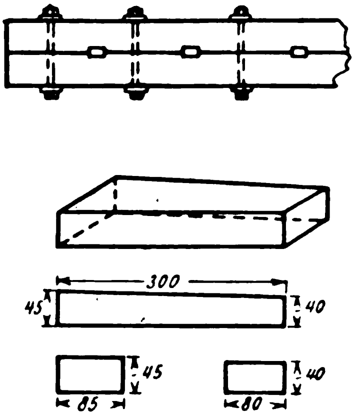


Fig. 102

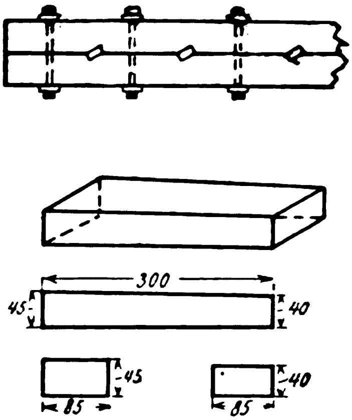


Fig. 103

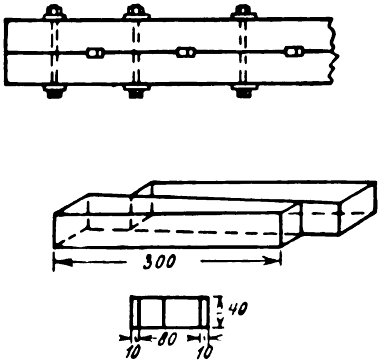


Fig 104

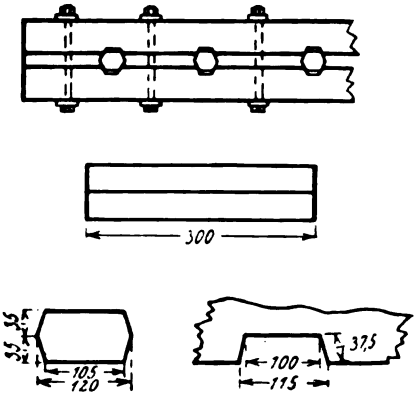


Fig 105

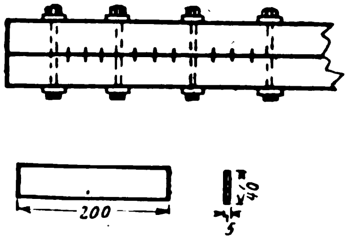


Fig 106

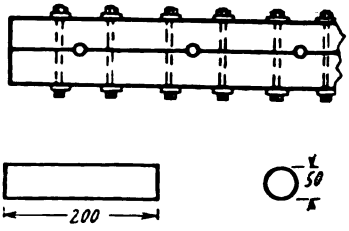


Fig 107

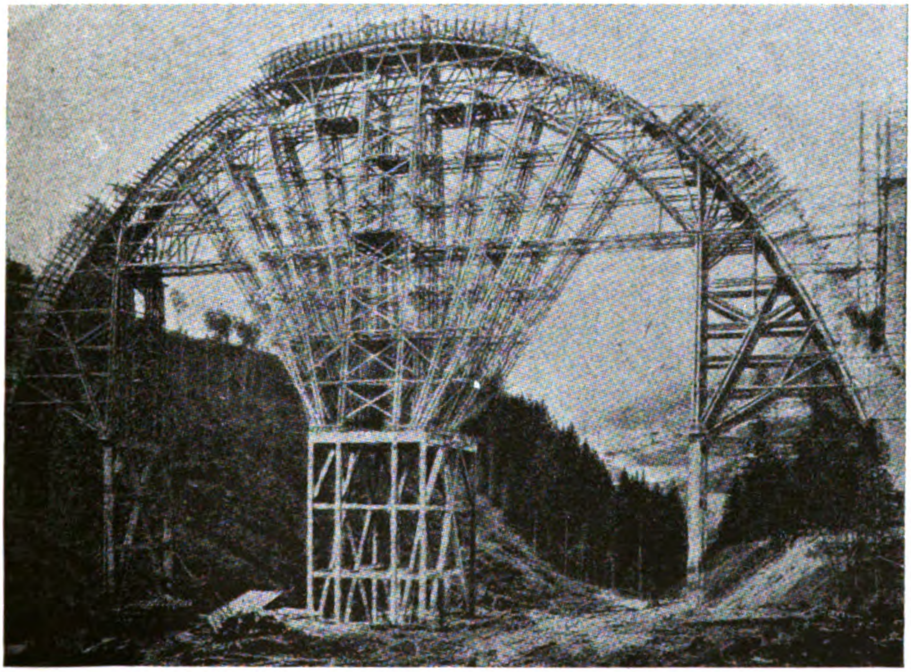
From *Rüstungsbau.*

DOWELS FOR BOLTING TIMBERS FOR A COMPOUND JOIST. (*See p.* 649.)

FORMWORK FOR CONCRETE CONSTRUCTION.

In preparing an estimate of the cost of a concrete structure the engineer is always confronted with the vexed question of the falsework with its attending staging, strutting, and bracing, the cost of which is generally more difficult to estimate than that of the actual components of the finished structure. Although the question of staging or other falsework comes into consideration in nearly all constructional work, it is mainly in concrete engineering that it assumes such proportions as to warrant very careful attention to detail. The truth of this will be evident when it is realised that the cost of the falsework very often amounts to about one-third or more of the whole constructional work. As this item accounts for so much of the capital outlay it would only be reasonable to assume that a great deal of attention is devoted to the planning and the general lay-out of this important feature, but unfortunately this is not always the case, and the preparation of the general arrangement and details of the falsework is only too often left to the foreman instead of being dealt with by the engineer and his staff. Only when the falsework is obviously beyond the foreman and requires real statical calculations, as in the case of long-span bridges with large free openings for traffic, does the contractor's engineer step in and treat the subject where it should always be dealt with—in the drawing office. In the past the contractor's engineer may have had good reasons for reluctance to deal with this part of the work, as there was no literature on this important subject, beyond what might be gleaned from the somewhat scrappy examples of staging occasionally illustrated in textbooks, and which in most cases did not fit in with his particular conditions.

This book * is, however, a very complete treatise on staging of all descriptions, and the engineer who wishes to approach



Langwies Viaduct: General View of Staging (River Bed Dry).

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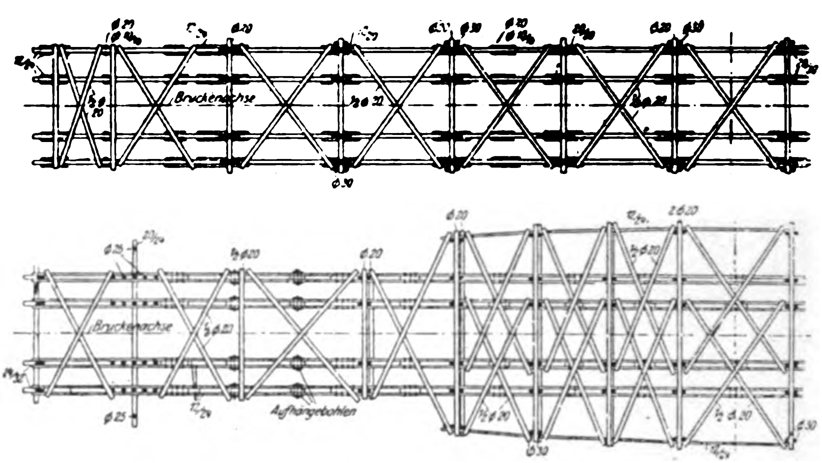
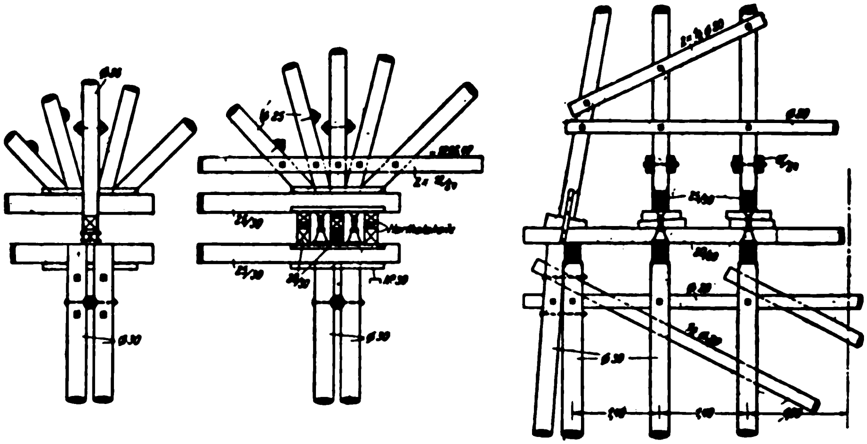
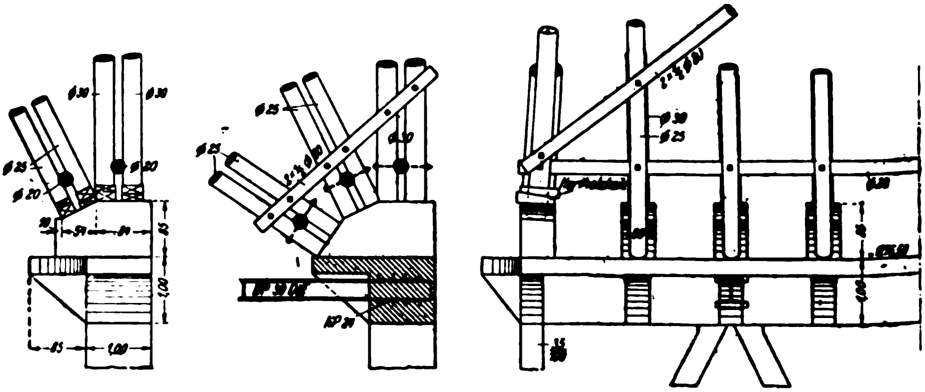
* *Rüstungsbau.* Scaffolding and Staging for Steel and Concrete Structures. By Professor H. Kirchner, Berlin: W. Ernst & Sohn. 232 pp., 486 illustrations. Price 20 frcs. (Swiss).



HORIZONTAL WIND BRACING.

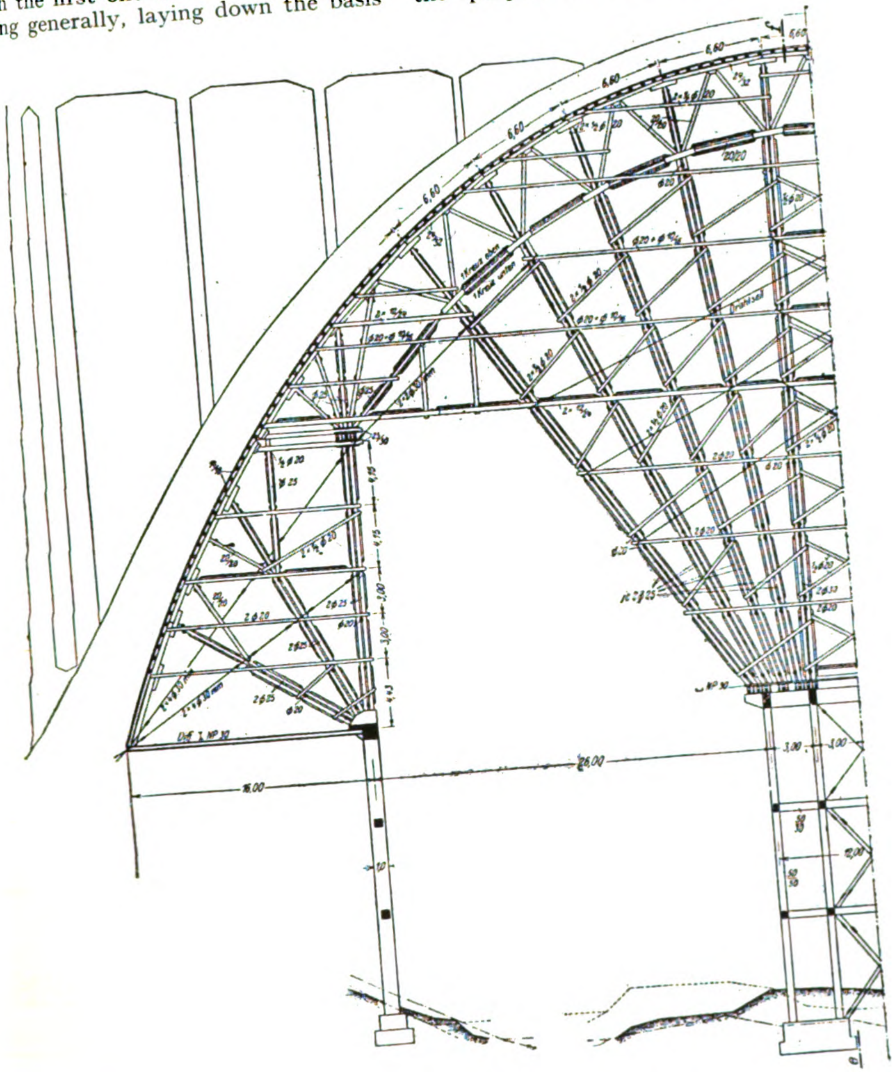


DETAILS OF END SUPPORTS FOR SUPERSTRUCTURE.

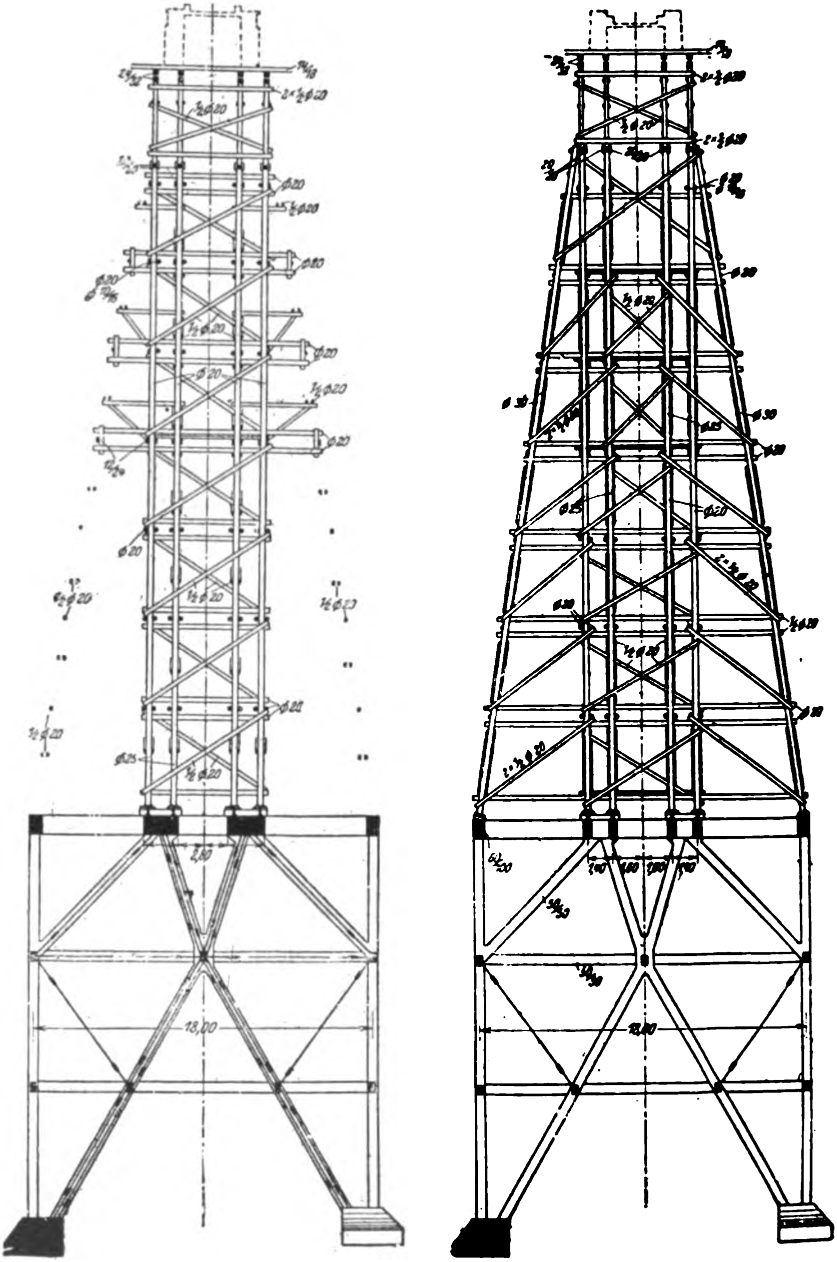


LANGWIES VIADUCT: DETAILS OF STRUTS AND BRACING AT SIDE TOWER.

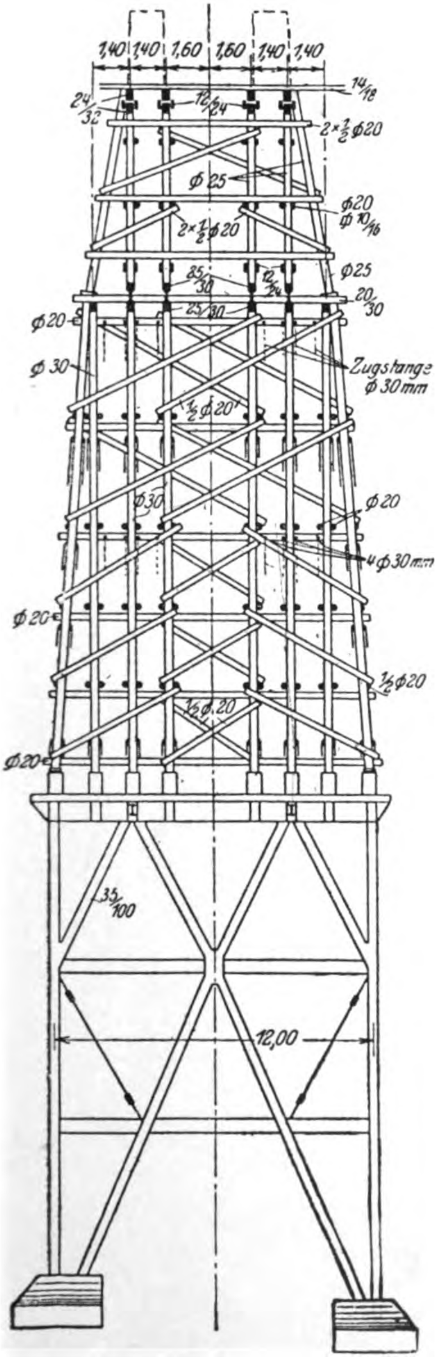
the question of staging design from the proper angle will find in it a wealth of information and good practical hints. The contents are not merely an enumeration and description of stagings already executed, but the subject of designing and building various kinds of stagings is dealt with in as serious and thorough a manner as bridge building itself. The book is divided into four chapters, of which the first one treats the subject of staging generally, laying down the basis for the calculation, the choice and properties of materials usually employed, the constructional details such as joints in timber and steel, supports, strutting, bracing, etc., simple and compound joists, lattice girders, trusses, and other methods of spanning large openings. As an example of the interesting details in this chapter a table may be mentioned giving the efficiency of various kinds of dowels as used in bolting timbers together for the purpose of making a compound



Staging for Langwies Viaduct : Side Elevation.



LANGWIES VIADUCT: CROSS-SECTIONS AT CENTRAL TOWER.



Langwies Viaduct: Cross-Section at End Tower.

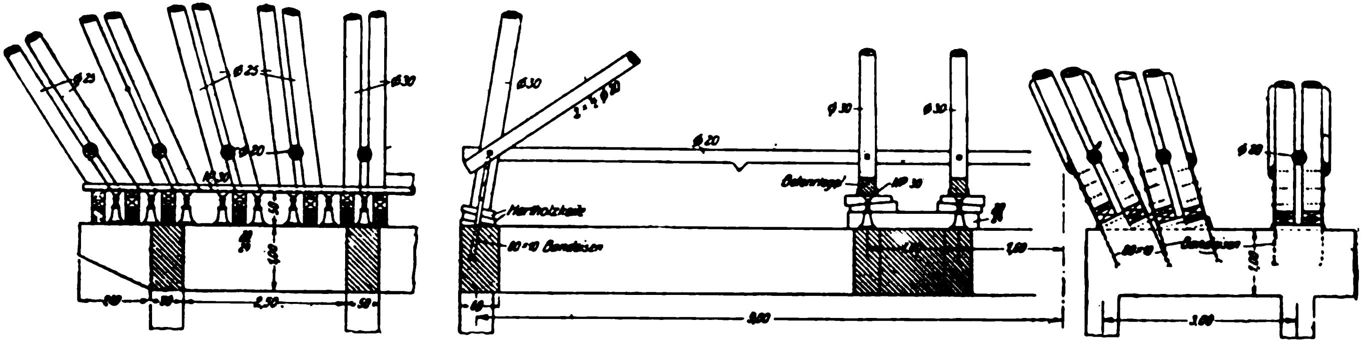
joist; a number of test results are given for the different forms of dowels illustrated in *Figs.* 102–107, as under:

TESTS ON DOWELS.

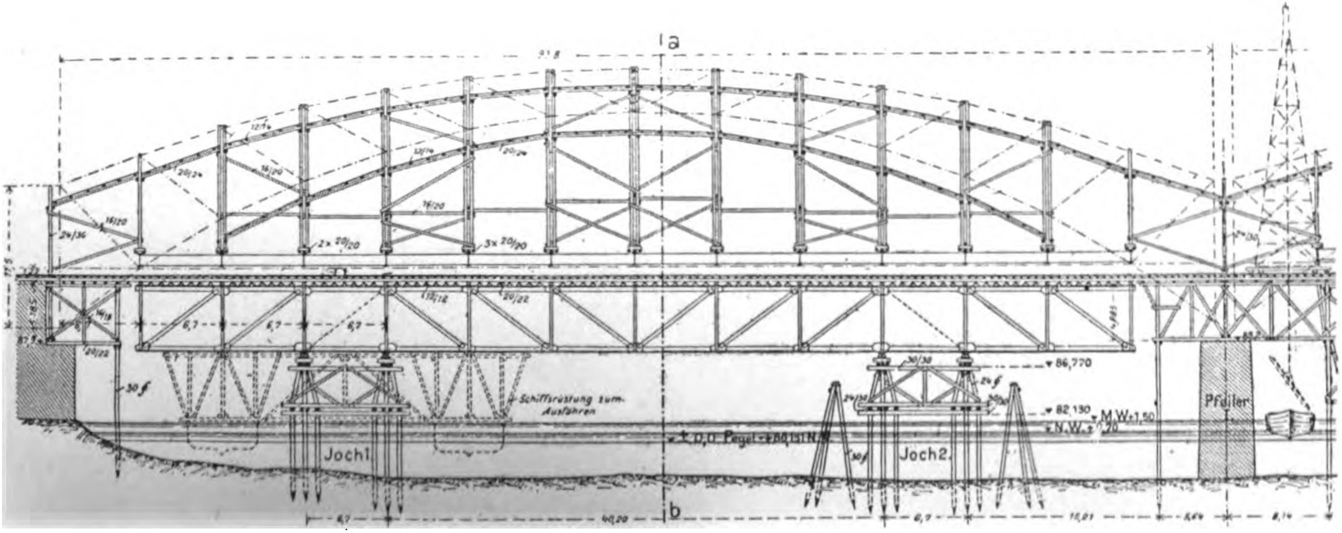
Nature of Dowel.	Material.	Fig. No.	Efficiency.
Single Wedge, horizontal	Oak	102	0·75
Single Wedge, inclined	Oak	103	0·80
Double Wedge . . .	Fir	104	0·78
Double Wedge . .	Oak	104	0·79
Hexagonal . . .	Oak	105	0·83
Flat strip on edge .	Steel	106	0·67
Round Bar . . .	Steel	107	0·85

The second chapter deals with staging for constructional steelwork, such as girder bridges of various descriptions, not only the usual staging for erection purposes, but also the special apparatus required for the shifting of the bridge, either longitudinally or transversely, as well as the floating tackle for erection by barge. The illustration of the staging for the railway bridge over the Rhine (see p. 654) gives one of many examples illustrating the latter procedure. In the third chapter the temporary staging for arch bridges is dealt with in all its phases, and some interesting samples are illustrated, such as those of the Langwies Viaduct also given from the book in this issue. The last chapter of the book is devoted to staging for loading, unloading, hoisting, and transporting materials, working scaffolding for different purposes, etc.

Owing to lack of space the details of centering for ordinary constructional concrete work, such as columns, beams and slabs, are omitted, it being considered that they are already fairly fully described in detail in most concrete textbooks, or else sufficiently simple to be left to the foreman.—R. N. S.



LANGWIES VIADUCT: DETAILS OF MAIN STRUTS AND WIND BRACING AT MIDDLE TOWER.



RAILWAY BRIDGE OVER THE RHINE: ELEVATION OF STAGING. (See p. 653.)

NEW METHODS OF CONCRETE COTTAGE CONSTRUCTION.

AN AUSTRALIAN SYSTEM.

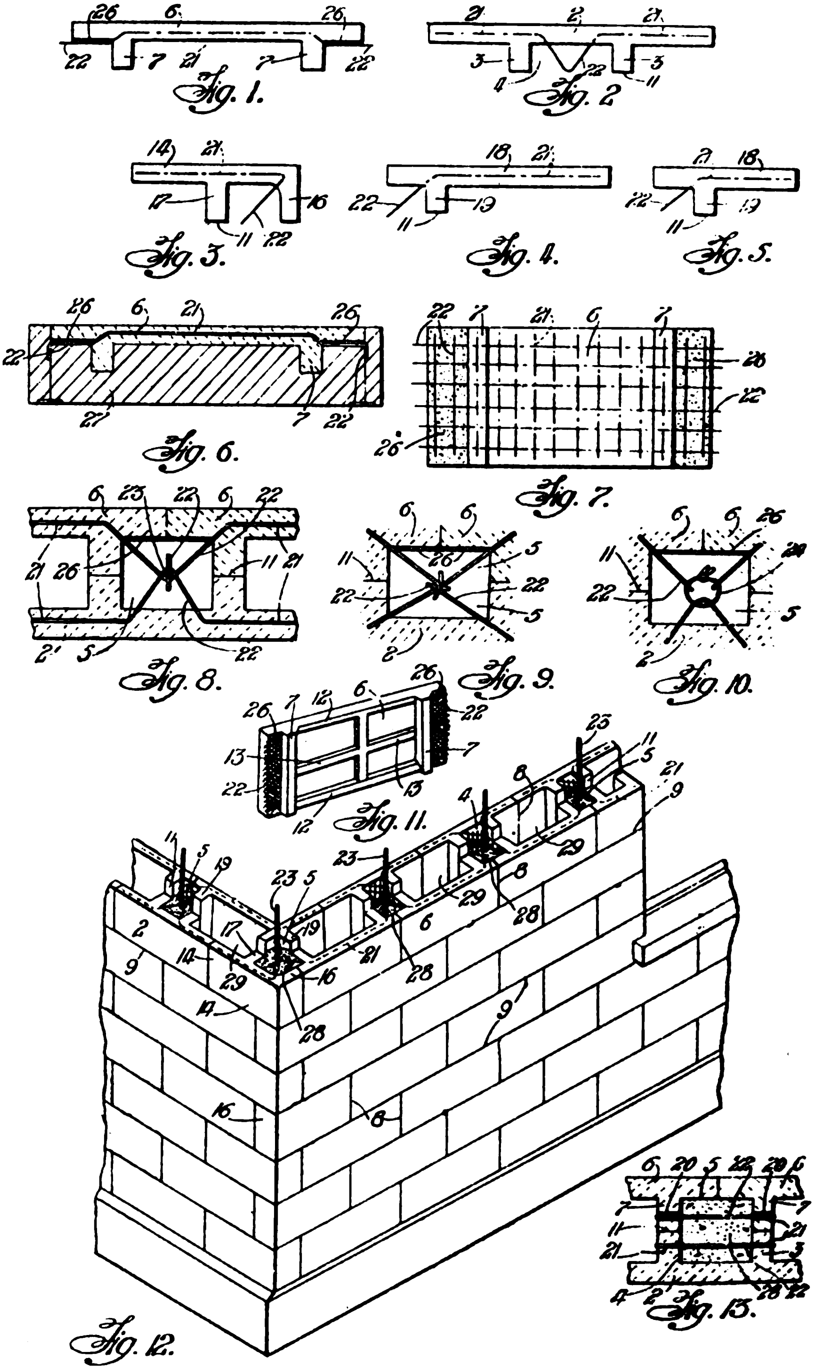
THE concrete house illustrated on this page is built on a system patented by Mr. A. C. Matthews, an Australian architect and engineer, whose present address is 44 Inverness Terrace, Hyde Park, W.; it is in Australia, where we are informed the system is extensively used.

As will be seen by the drawings on page 656, the walling is built of concrete slabs with end and intermediate ribs which when assembled form vertical enclosures at the ends of certain slabs and at the middle of opposite slabs. Within the enclosures formed at the ends of the slabs concrete is poured to form columns. *Figs.* 1 and 2 show, on plan, the two types of slab used; *Fig.* 3 is a plan of an external corner slab; *Figs.* 4 and 5 are plans of internal corner slabs. The method of moulding the slab so that the projecting ends or anchor portions of the reinforcement are prevented from adhering to the plastic material is illustrated in *Fig.* 6. A view of the inner side of the slab seen in *Fig.* 1 is given in *Fig.* 7. A method of uniting the projecting anchor portions of the reinforcement of opposite slabs in the solid columns is shown in *Fig.* 8, while alternative methods of obtaining the same result are given in *Figs.* 9 and 10. A perspective view of a slab, showing the strengthening ribs on the inside, is given in *Fig.* 11. *Fig.* 12 is a perspective view of a corner portion of walling showing the invention in use.

Certain slabs (2) are provided with an intermediate pair of integral ribs (3) which project from one side of the slab

[*Mr. A. C. Matthews, Architect.*

CONCRETE HOUSE IN AUSTRALIA.



AN AUSTRALIAN METHOD OF CONCRETE-BLOCK CONSTRUCTION.

near its middle and extend vertically thereof. These intermediate ribs form between them a vertical channel indicated at (4), which forms half of one of the vertical passages or enclosures indicated by (5). Other slabs (6) are provided with end ribs (7) one of which is disposed near each end of the slab. These end ribs are adapted to co-operate with the intermediate ribs (3) of opposite slabs to form the vertical enclosures (5).

As seen in *Fig.* 12 the vertical joints (8) between the ends of adjoining slabs, forming the inner section of a double wall, are staggered so that moisture cannot pass directly through the vertical joints of the inner and outer wall sections. Similarly the horizontal joints (9) of the inner and outer sections of the wall are disposed out of alignment with each other by inserting at the bottom of one section slabs of half the height of the bottom slabs of the other wall section. The joints (8) and (9) are grouted in the usual manner. The outer or abutting ends (11) of the ribs forming the enclosures may also be grouted. To provide a larger jointing surface around the edges of the slabs, the top and bottom and ends thereof may be thickened or enlarged as at (12) in *Fig.* 11, which also shows strengthening ribs (13) extending across the inner face of the slab. The provision of these ribs and thickened edges permits of a saving of material in the body of the slab without unduly weakening it.

The corner slab seen in *Fig.* 3 is provided with a single outstanding rib (17). When slabs of this type are fitted into the corner of a building the parts (16) and (17) form part of one of the vertical enclosures (5).

The slabs illustrated in *Figs.* 4 and 5 may also be used at corners as shown in *Fig.* 12 and comprise a straight body portion (18) from which a rib (19) outstands near one end of the slab, this rib forming part of one of the enclosures (5) when the slabs are assembled.

Each slab has embedded within it a metal reinforcement (21) provided with projecting ends or anchor portions (22). In the case of the intermediately ribbed slabs, as seen in *Fig.* 2, these projecting anchor portions protrude into the vertical channel (4) between the intermediate ribs (3). In the case of slabs having end ribs as in *Fig.* 1 the anchor portions protrude through the inner side of the slab between each end thereof and the adjacent rib (7). In all cases the projecting anchor portions of the reinforcement are so disposed as to be located within the enclosures (5) when the slabs are assembled.

The projecting anchor portions (22) may be looped or otherwise suitably shaped to facilitate the fastening together of the anchor portions of adjacent slabs within the vertical enclosures formed by the ribs when the slabs are assembled to form a double wall. Thus, as shown in *Figs.* 2, 8 and 10, the anchor portions project in the form of a **V** into the channel formed between the ribs (3), the intermediate portion of the reinforcement being bent outwardly in this manner.

The anchor portions of the reinforcement may be fastened together in any suitable manner, a convenient means consisting in disposing vertical reinforcing rods or wires (23) within the vertical enclosures and twisting or passing the anchor portions around vertical rods, as in *Figs.* 8 and 12.

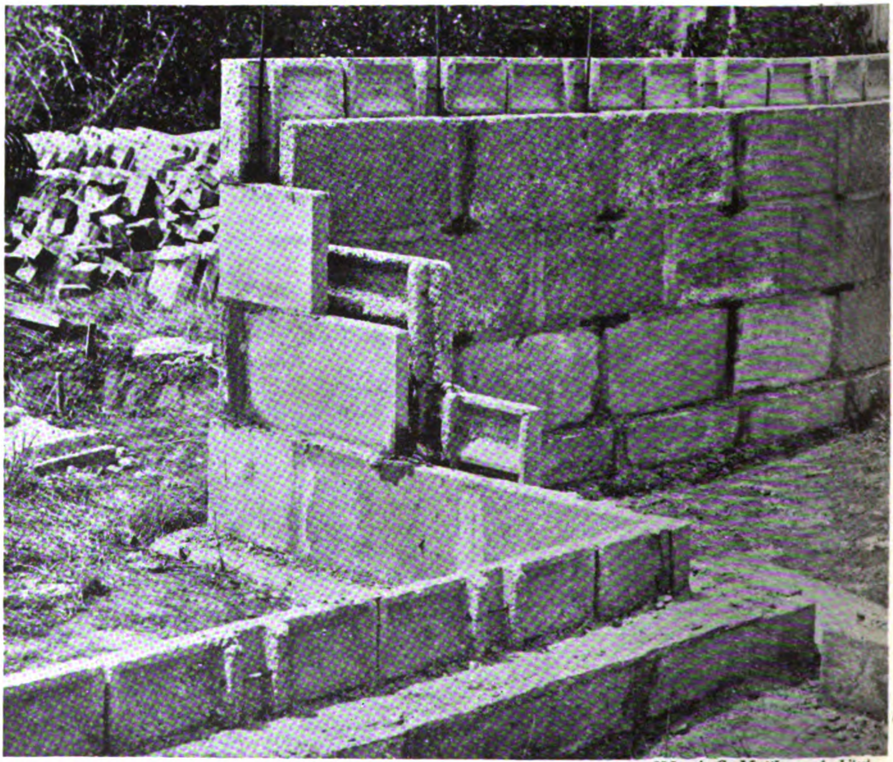
To prevent the projecting ends or anchor portions (22) of the reinforcement adhering to the plastic material when the slabs are being moulded, strips (26) of suitable material such as tar paper may be interposed between the anchor portions and the adjacent inner surface of the slab by laying the strips in the anchor portions of the reinforcement after the latter has been laid on the mould (27) and before the plastic material has been introduced into the mould as seen in *Fig.* 6. Thus when the slab has dried the projecting anchor portions are free to be turned outward for attachment to the anchor portions of opposite slabs as in *Figs.* 8, 9 and 10. The strips (26) may be left adhering to the slab and thus form a damp-proof lining on one side of the enclosures (5) which accommodate the plastic material to form the vertical columns (28).

When a series of slabs has been assembled to form a double wall and with the ends (11) of the ribs of opposite slabs abutting, as in *Figs.* 8 to 10 and 12, a series of the vertical enclosures (5) of substantially rectangular cross section are formed between the slabs of the inner and outer wall sections. These enclosures divide the air space (29) between the inner and outer wall sections into a series of compartments. The projecting anchor portions of the reinforcement may now be fastened together by passing around the vertical rods or wires (23), or by other suitable means within the enclosures, so that the series of slabs are held together prior to the pouring in of the material to form the vertical columns (28). A considerable section of a wall or the like may thus be erected before the plastic material is introduced into the enclosures (5). By arranging the inner and outer wall sections with the horizontal joints out of alignment, the projecting anchor portions of the reinforcement are easily accessible for fastening together.

When the plastic material is poured into the enclosures (5) between the inner and outer wall sections the slabs are securely and permanently bound together and the columns (28) are reinforced by the anchor portions of the reinforcement which are permanently embedded therein.

In a simplified and preferred embodiment of the invention as seen in *Fig.* 13, the reinforcements or ties (21) extend transversely between the adjoining parallel ribs and thus bridge the enclosures (5) in the direction of the slab's length. These transverse reinforcements may be embedded in the ribs during manufacture of the slab, or may be formed through the ribs (7) during or subsequent to manufacture and the reinforcing wires passed through the holes when the slabs are being assembled.

The outstanding features claimed for this method are as follows :—An average saving of from £100 to £150 in an ordinary brick dwelling ; the average time to erect the walls of a 5-room house with 5 men is 4 days ; men may easily be found to make segments ; perfect insulation from external temperatures and damp ; weight of walls is one-third of brick walls.



[*Mr. A. C. Matthews, Architect.*

AN AUSTRALIAN METHOD OF CONCRETE-BLOCK CONSTRUCTION.

IN SITU CONCRETE COTTAGE CONSTRUCTION.

A NOVEL system of concrete wall construction, known as the " R.C.C." system, has been patented by Messrs. The Rogers Construction Co., Ltd., of 9 Park Place, St. James's, S.W.1. The feature of this system is the reinforcement, which takes the form of flat sheets of sheet steel from 26 to 30 gauge stamped as shown in *Fig.* 1. The four triangular pieces in each of the forty-eight separate stampings in the steel sheet are bent two outwards and two inwards so as to form tangs, or wings, projecting from each face of the sheet. Two of these sheets are then placed face to face and fastened together by clips locking the tangs on each sheet where they come into juxtaposition.

The object of this type of reinforcement is two-fold : (1) to impart tensile strength to the wall, and (2) to make it possible to release shuttering sooner because of the support given to the concrete by the tangs which are embedded in it, as shown in section in *Fig.* 2. It is also claimed that to a certain extent the reinforcement acts as a vertical dampcourse, and that any moisture which might penetrate the wall from the outside will be checked by the sheet metal in its centre and be conducted downwards. Any design may be followed with the reinforcement, as it may be readily cut on the site with shears.

The method of constructing walls with this reinforcement is as follows. The footings are laid with a longitudinal groove (1 in. in depth) in order to give a bond to the wall (see *Fig.* 2). Timber uprights are then placed at intervals around the building, as seen in *Fig.* 3, at distances apart according to the length of the shuttering units to be used, and as these are raised by hand a length of about 10 ft. is found convenient. These uprights are braced to be perfectly vertical and serve as guides for the shuttering, thus ensuring the wall being built true. Similar uprights are erected on both sides of the wall. Those on the outside are built to the full height of the wall to be built. The uprights on the inside, if the building is to be of more than one story, are erected to the height of the first story only ; they are then taken down and re-erected on the first-floor joists to continue the wall upwards, and so on for any number of stories.

After the footings and uprights, or shutter-guides, are in place, the shuttering is placed in position for the first pour. The shuttering used is of timber with a steel plate on the face to facilitate drawing it upwards and to obtain a good surface finish to the concrete. On each side of the uprights is a steel angle throughout its

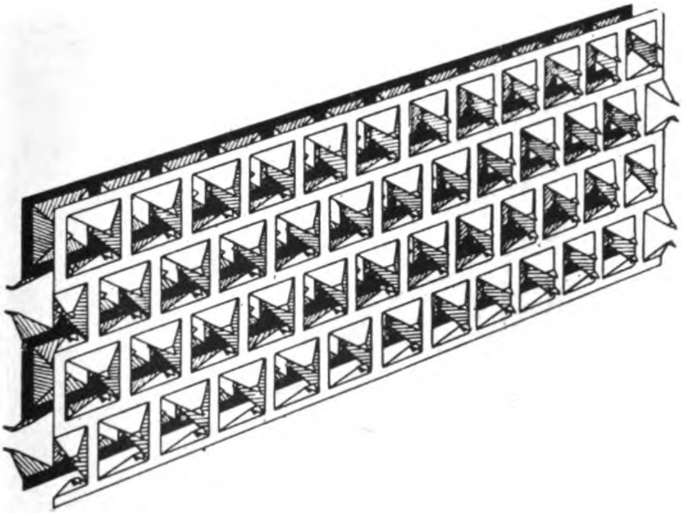
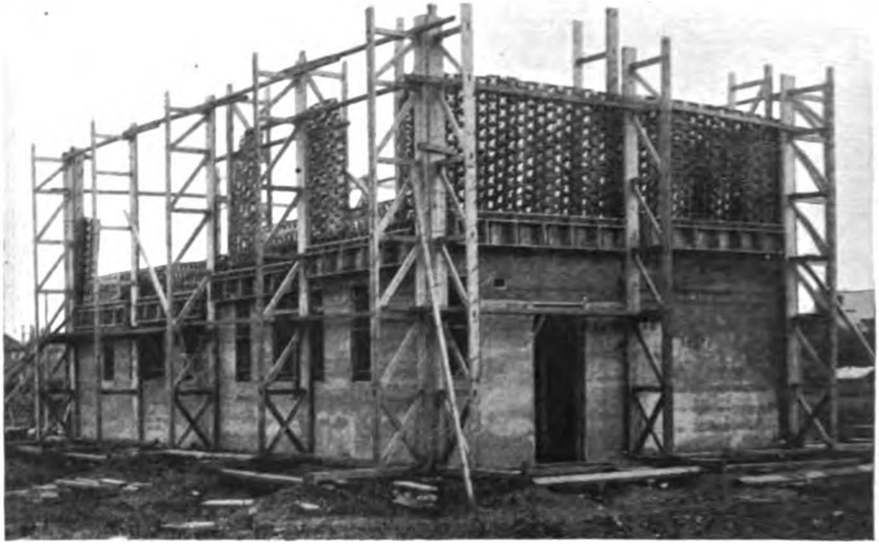
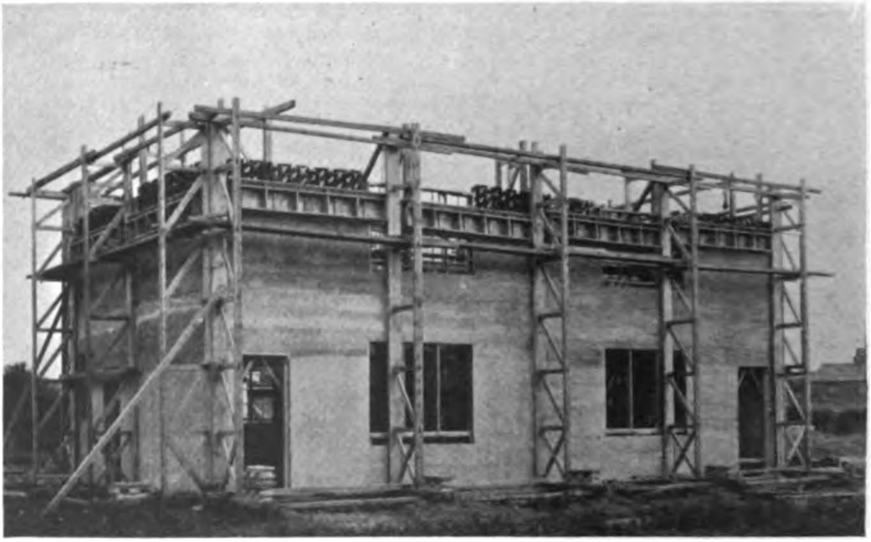


FIG. 1.—" R.C.C." REINFORCEMENT.



After Two Days' Work.



After Three Day Work.

PAIR OF COTTAGES AT FELTHAM BUILT ON THE "R.C.C." SYSTEM.

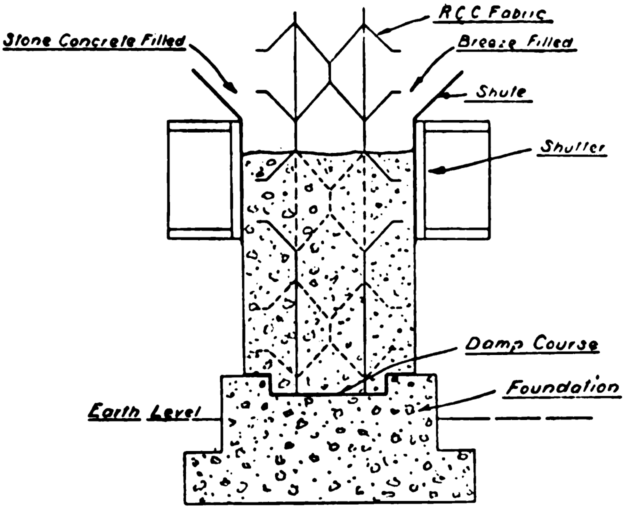


FIG. 2.—" R.C.C." METHOD OF CONSTRUCTION.

length, and inside this and resting against it outwardly the shutters are placed. They are not fixed in any way, the steel angles on the uprights preventing them from being forced outwards by the weight of the concrete, which also prevents them from falling inwards. The shutters are 15 in. in height, and are provided with a top board sloping inwards which guides the concrete down between them. Sheets of reinforcement are then placed in position in the middle of the shutters and concrete placed from each side simultaneously and tamped into the space between the two locked sheets of steel. In placing the reinforcement the sheets are erected alternately with one standing on end (6 ft. high by 2 ft. wide) and three superimposed one above the other on edge, filling an area 6 ft. by 6 ft.

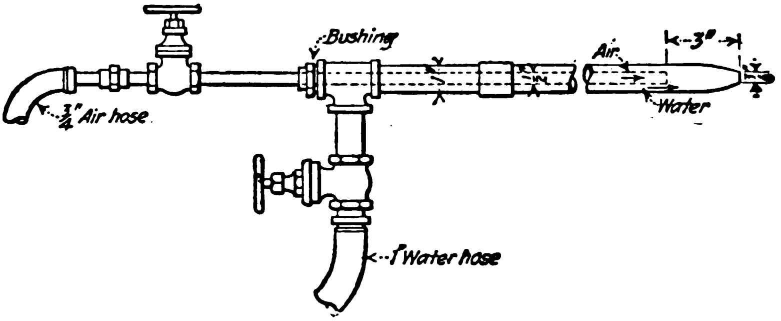
It is possible for two men to fill shutters 10 ft. long by 15 in. deep in about 30 minutes. They then lift the shutters 6 in. higher and again fill them, and so on to the top of the wall. The concrete is thus left unsupported very soon after it is laid, and it is in making possible this rapid release of shuttering without waiting for the concrete to set that the chief advantage is claimed for the system, in that it is claimed that it is the support given to the concrete by the projecting tangs on the reinforcement which permits the shuttering to be removed so soon. This speedy removal of the formwork also makes it an easy matter to brush off the surface film of cement and expose the aggregate, and this method of surface treatment is adopted by the patentees for buildings erected on their system.

As will be seen the reinforcement, being in the form of perforated sheets, practically divides the wall into two leaves. This is taken advantage of to form a wall of weather-proof gravel concrete on the outside and a breeze concrete, to avoid condensation, on the inside, and as the gravel and breeze concrete are placed simultaneously, and to a certain extent intermingled as operatives on each side of the wall tamp between the reinforcement, an excellent bond is obtained. Interior partition walls are built entirely of breeze concrete, with only one sheet of reinforcement.

This system obviates the necessity of searching for any skilled labour for the erection of the shell of a house, and, we are informed, works out at about 25 per cent. less cost than brickwork.

CLEANING CONCRETE SURFACES.

In the construction of the Weid Canyon dam which is being built by the city of Los Angeles as part of its water distribution system, *Engineering News Record* states that a combination air and water jet has been developed which has proved to be a very effective means of cleaning off concrete so as to afford a rough, hard surface free of all foreign matter, and a good bond for the next concrete to be poured. The device consists essentially of two pipes one within the other whereby the spouting velocity of the water issuing from one of the pipes is increased by the compressed air issuing from the other pipe.



Combination Air and Water Jet for Cleaning Concrete Surfaces.

Air and water are brought to the device in rubber hose of ¾-in. and 1-in. diameters, respectively, the water being under heads ranging up to 300 ft. and the air under a pressure of 90 to 100 lb. per sq. in. The air hose terminates in a ½-in. pipe inside a 1-in. pipe which carries the water, the relative position of the two outlets being arranged as shown in the accompanying sketch. The over-all length of the pipe-nozzle is about 4 ft.

Two men are used to operate this device, one to manipulate the nozzle and a second to drag the hose so the operator can work to best advantage. The effect of the combined air and water jet is to leave the surface remarkably clean with rough, sharp corners where all small particles not firmly embedded have been washed away. Most of the water used in washing flows off because the surface of the concrete is kept sloping downward toward the upstream face of the dam. Pools which form from the water collecting in hollows are baled out and wiped up before concrete pouring begins.

The work on Weid Canyon dam is under the general direction of Mr. William Mulholland, chief engineer, Los Angeles Bureau of Water Works and Supply. Mr. H. L. Jacques, who developed the jet described, is superintendent of construction.

CORRESPONDENCE.

CONCRETE PROPORTIONS.

Sir,—It is useless to discuss the question of costs from opposed points of view. Those who practise will understand such divergence of opinion, and, while appreciating with Sir Owen Williams the advantages of having a rich mix, will agree that—unless concrete construction is to be a luxury where it is now a necessity—enough is enough.

Charles Marques.

CONCRETE PRODUCTS

REINFORCED CONCRETE PRESSURE PIPES.

REINFORCED concrete pipes for the transmission of water under pressure have been adopted to a very large extent in the United States and Canada, where they are now used for the domestic water supply system of many important cities. Although at first used for conveying water at moderate pressures, i.e. under 100 ft of head, they are now used for pressures of over 200 ft. head by such important water supply authorities as the United States Reclamation Service, and reinforced concrete pipes are fairly generally adopted for all pressures ordinarily met with in municipal domestic supply systems. The lengths generally made are 10 ft. and 12 ft., and while they are made in all diameters up to 108 in. it is not usual to use a size smaller than 15 in. diameter.

As in this country reinforced concrete pipes for carrying water under pressure are not so largely used, the following notes on American methods, taken from a paper recently read before the Concrete Institute by Mr. W. G. Chace of the Lock Joint Pipe Co., may be of interest :—

While in service a well-designed and well-built reinforced concrete pipe cannot be destroyed by rise of pressure so as to allow all the water to escape, or so as to cause the pressure at the point of delivery to fall seriously below normal. Such a pipe is a body of dense concrete within which is a network of steel worked at low stresses. A surge of water pressure may temporarily tear the concrete by setting up extraordinary stresses in the reinforcement, but a section of pipe wall is never blown out nor is any large portion of the conveyed water allowed to escape. Rarely would the reinforcing steel be so stressed beyond its elastic limit, and in nearly every case the loss of water would cease when the moment of temporary extra water pressure had passed. This feature is of immense importance in securing a continuity of municipal supply, thereby minimising fire risk, sanitary risk, and commercial loss.

The interior surface of pipe units is smooth, having been moulded against smooth and oiled steel forms. The interior of a pipe-line of reinforced concrete pipes is continuously smooth, even at the joints, and there are no projecting obstructions, transverse grooves, or irregularities of line or diameter such as would set up eddies in the flowing stream and thus reduce the capacity of the system. The use of reinforced concrete pipes in transmission mains results in small

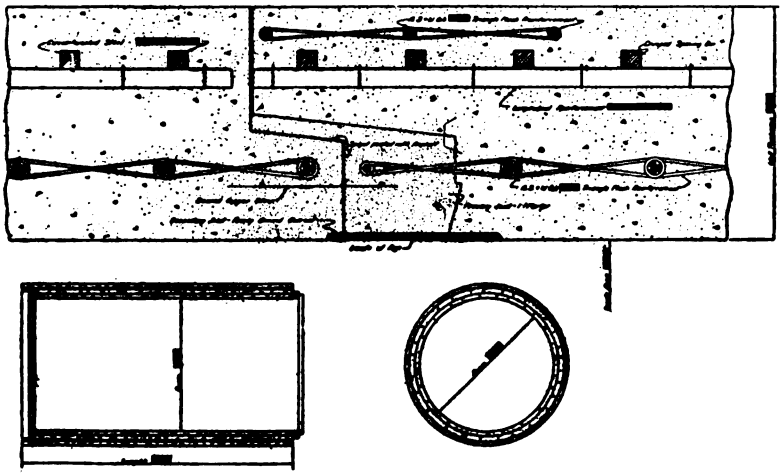
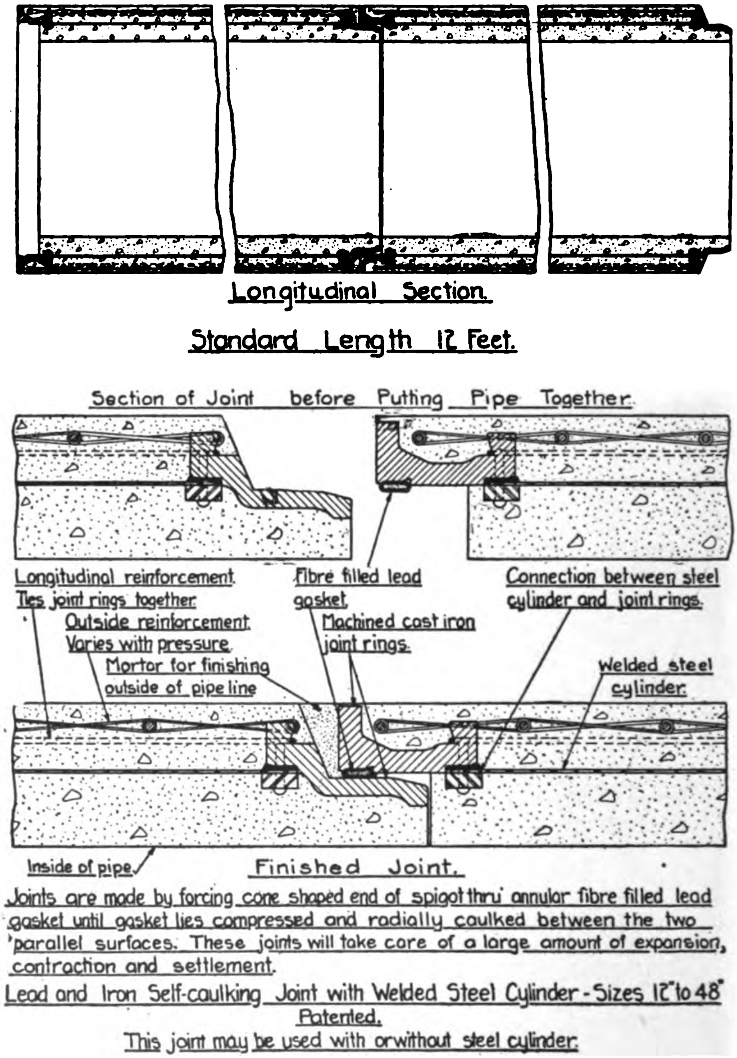


FIG. 1.—DETAILS OF REINFORCED CONCRETE PIPE FOR HIGH HEAD.


Longitudinal Section
Standard Length 12 Feet.
Section of Joint before Putting Pipe Together.
Longitudinal reinforcement. Ties joint rings together.
Outside reinforcement. Varies with pressure.
Mortar for finishing outside of pipe line
Fibre filled lead gasket
Machined cast iron joint rings.
Connection between steel cylinder and joint rings.
Welded steel cylinder.
Inside of pipe.
Finished Joint.

Joints are made by forcing cone shaped end of spigot thru' annular fibre filled lead gasket until gasket lies compressed and radially caulked between the two parallel surfaces. These joints will take care of a large amount of expansion, contraction and settlement.

Lead and Iron Self-caulking Joint with Welded Steel Cylinder - Sizes 12" to 48"
Patented.
This joint may be used with or without steel cylinder.

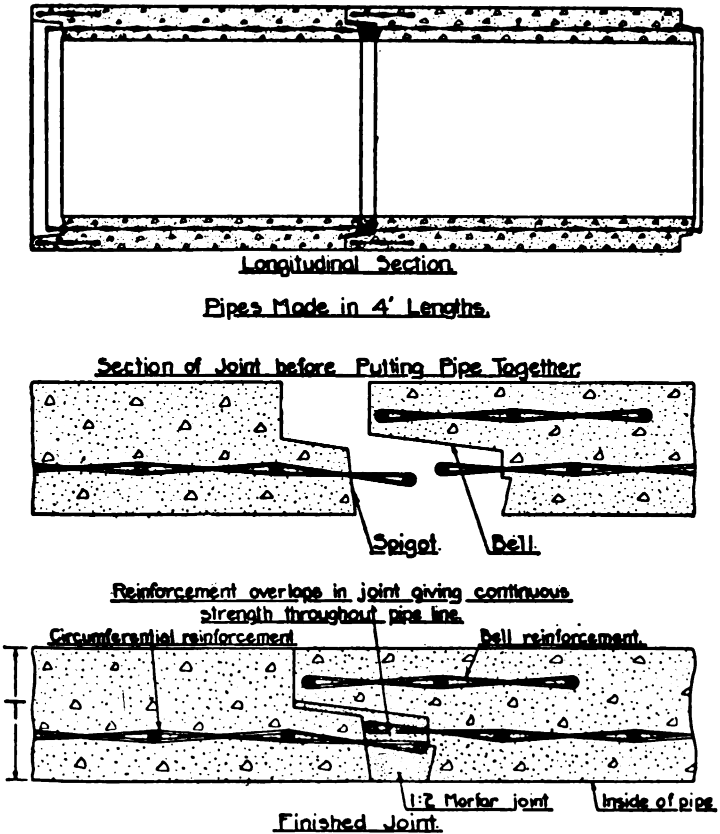
FIG. 2.—LEAD AND IRON SELF-CAULKING JOINT WITH WELDED STEEL CYLINDER.
SIZES 12-IN. TO 48-IN.

losses of pressure and in highest delivery pressures.

The walls of well-made reinforced concrete pipes, made of a rich mixture of cement and selected aggregate, are of low permeability and lose water under the higher pressures by "sweating" only. The loss per mile is very moderate, varying with the pressure of water and the age of the concrete. These losses are not more than those found in pipe-lines of steel and cast iron; and, unlike the losses from steel or cast iron pipes, which increase with the age of the pipes, those occurring with reinforced concrete pipes are greatest at the date of initial service and decrease as the pores of the concrete become filled.

Joint devices which remain water-tight in spite of changes of length or changes of temperature are absolutely essential, and now all reinforced concrete pipes for the supply of domestic water, whether under pressure or not, are equipped with expansion devices in each joint. These joints are so designed that even if the temperature contraction of several pipes should all appear at one place the partial opening of the joint would not allow any water to escape.

Two general types of expansion joint are used. One of these, the "copper joint," consists of a beaded copper ribbon secured within the spigot rim, the other edge of which is then jointed with mortar to the inner annulus of the


Longitudinal Section.
Pipes Made in 4' Lengths.
Section of Joint before Putting Pipe Together
Spigot.
Bell.
Reinforcement overlaps in joint giving continuous strength throughout pipe line.
Circumferential reinforcement
Bell reinforcement.
T
1:2 Mortar joint
Inside of pipe
Finished Joint.

Dia.	24"	27"	30"	33"	36"	39"	42"	45"	48"	54"	60"	66"	72"	78"	84"	90"	96"	108"
T	3"	3½"	3½"	4"	4"	4"	4½"	4½"	5"	5½"	6"	6½"	7"	8"	8"	8½"	8½"	9"

FIG. 3.—REINFORCED CONCRETE SEWER PIPE. SIZES 24-IN. TO 108-IN.

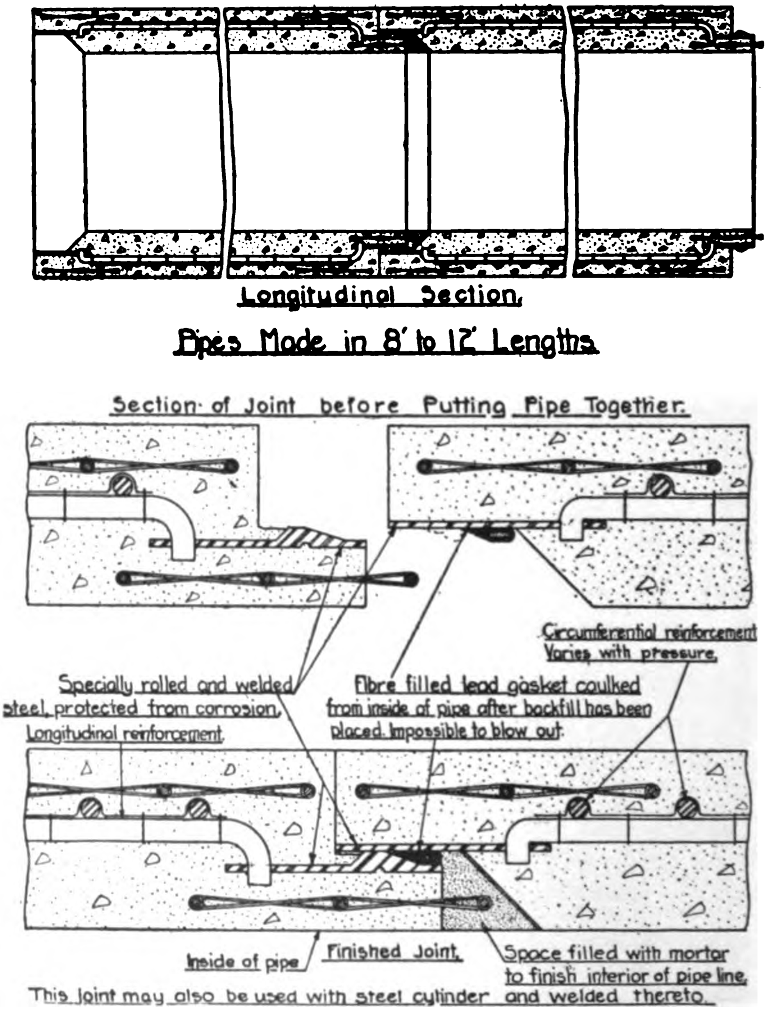

Longitudinal Section,
Pipes Made in 8' to 12' Lengths.
Section of Joint before Putting Pipe Together.
Circumferential reinforcement Varies with pressure.
Specially rolled and welded steel, protected from corrosion.
Longitudinal reinforcement.
Fibre filled lead gasket caulked from inside of pipe after backfill has been placed. Impossible to blow out.
Inside of pipe
Finished Joint.
Space filled with mortar to finish interior of pipe line.
This joint may also be used with steel cylinder and welded thereto.

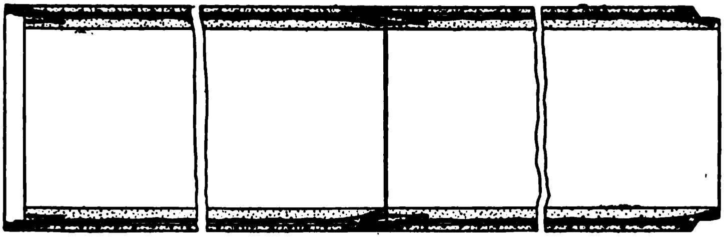
FIG. 4.—LEAD AND STEEL JOINTS, FOR SIZES FROM 36-IN. TO 108-IN.

bell after the pipes have been placed in position in the trench (see *Fig.* 2). The other type comprises an elastic fibre-filled lead gasket, caulked between smooth or machined steel surface of bell and spigot specials. This latter type is used in two forms, the "lead and iron" joint and the "lead and steel" joint.

Of these two forms of metal joint the former, the "lead and iron" joint, utilises a flanged iron bell casting having a wedge-shape groove machined within its periphery and a spigot casting machined to a conical form on its end and to a cylindrical form immediately behind the cone and upon which the gasket rides after the joint has been made. A forced entry of the spigot of one pipe into the ring gasket lying inside the bell of the next pipe unit caulks the gasket radially for its entire width and forces it into the wedge groove in the bell (*Fig.* 3).

The "lead and steel" joint comprises a plain band of steel of sufficient width as a bell fitting and a special band bearing a conical rib as a spigot fitting. The fibre-filled lead gasket is of special shape; it is laid as a ring within the bell rim and after the entry of the spigot is caulked into position from within the pipe (*Fig.* 4).

The "copper" joint, the "lead and iron" joint, and the "lead and steel" joint remain watertight even though deflected by settlement of the pipe foundation or by movement of the back-filled earth. The "copper" joint and the "lead and steel" joint are used within pipes whose diameters permit men to work within the pipes, while the "lead and iron" joint may be used with smaller diameters.



Longitudinal Section

Standard Length 12 Feet

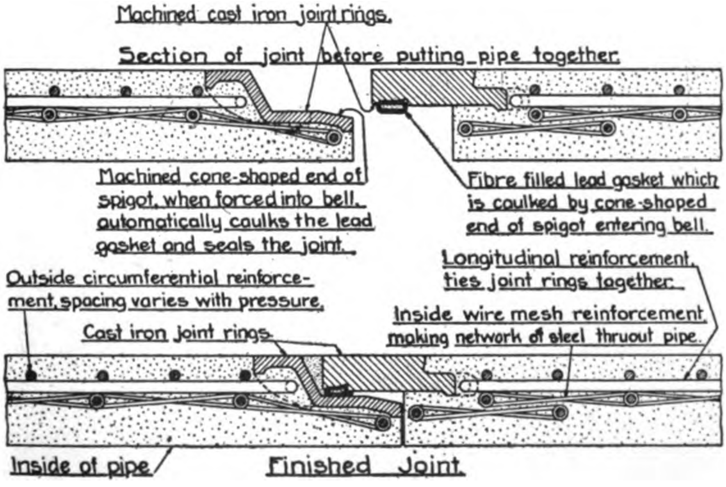

Machined cast iron joint rings.
Section of joint before putting pipe together.
Machined cone-shaped end of spigot, when forced into bell, automatically caulks the lead gasket and seals the joint.
Fibre filled lead gasket which is caulked by cone-shaped end of spigot entering bell.
Outside circumferential reinforcement, spacing varies with pressure.
Longitudinal reinforcement ties joint rings together.
Cast iron joint rings.
Inside wire mesh reinforcement making network of steel thruout pipe.
Inside of pipe
Finished Joint

FIG. 5.—CENTRIFUGALLY-MADE REINFORCED CONCRETE PRESSURE PIPE WITH LEAD AND IRON SELF-CAULKING EXPANSION JOINTS.

Properly-made reinforced concrete pipes are strong not only against the bursting pressure of the conveyed water but also against earth pressure from the back-fill. The wall is thicker than is the case with metal pipes, and the reinforcement is so distributed through the wall section as to take care of earth loads. To get the maximum value from a pipe under extreme superimposed loads it is necessary that they be properly bedded and that the trench be properly back-filled. There are no initial stresses in reinforced concrete pipes such as occur with metal pipes.

Experience has proved the durability of concrete in all structures, and especially in buried structures. Experience has also proved that steel within good concrete, if provided with sufficient external cover, is free from corrosion and therefore permanent. No waterproofing, tar coating, painting, or other protection is necessary, nor is there any maintenance cost. The author has inspected reinforced concrete pipes after sixty years' service and found them in uniformly good condition, and quite fit to repeat that period of service.

As to the economy of reinforced concrete pipes, it has to be remembered first that there is no maintenance charges. Also it is moderate in first cost, and the labour employed is not the most expensive. The pipes are generally made close to the site of the installation, so that freight and handling charges are kept to a minimum. They are laid without the use of hot lead or hot rivets, and therefore without the employment of specialised trades. In practically every district sand and coarse aggregate may be found locally, and local labour may be employed for the manufacture of the pipes instead of purchasing them from a distant factory.

When the pipes are made by pouring concrete into steel moulds, a bar or mesh reinforcement is used for the lower pressures and similar reinforcement supplemented by a sheet-steel cylinder to reduce seepage through the necessarily thin walls of the pipe. *Figs.* 2 and 4 illustrate pipes reinforced with mesh and with bars, while *Fig.* 3 shows the sheet steel reinforcement. The former method of reinforcement is used where pressure heads do not exceed about 40 lbs. per sq. in. Where the pressure is greater it is difficult to prevent seepage without the use of the sheet-steel cylinder.

In the centrifugal process of manufacture, an outside watertight steel form, properly equipped with end rings, within which has been placed the cage of reinforcement bearing the joint fittings, is rotated at high speed, the concrete being fed uniformly throughout the length of the mould, and while still rotating, the inner surface is cleaned up and trued. The pipes are cured with steam for one day within the moulds and for one or two days after the moulds are removed. Concrete pipes are made by the centrifugal process in diameters of from 12 in. to 36 in., without the sheet-steel reinforcement. The concrete is composed of cement, sand, and water, and is so compacted as to be practically impervious; its density may be judged by the fact that concrete made by this method weighs 150 lb. per cu. ft. Centrifugally-made reinforced concrete pipes, like those made by any other process, can be a success only when made with scientifically-designed and accurately-made joints, firmly secured within the body of each section (see *Fig.* 5).

THE FOREMAN'S GUIDE TO CONCRETE.

A MANUAL FOR ALL ENGAGED IN CARRYING OUT CONCRETE AND REINFORCED CONCRETE STRUCTURES.

By ALBERT LAKEMAN, M.S.A., M.I.Struct.E.

INTRODUCTION.

NUMEROUS excellent books dealing with reinforced concrete have been published during recent years, and both theory and practice have been treated in a thorough manner from the engineering student's point of view, but a simple treatise for the guidance of the clerk-of-works, foreman, and general concreter does not appear to be available. On many schemes the author has observed a tendency on the part of the foreman to overlook the importance of certain essential points in the execution of the work, and upon the matter being discussed in nearly every instance it has been found that the primary cause is the lack of simple theoretical knowledge on the part of those engaged in the direct control of the workmen. Some of the concrete failures that have occurred in the past could undoubtedly be traced back to this cause, and the practical man on the job is not entirely to blame unless it can be shown that he has neglected a real opportunity to learn something about the material from the designer's point of view.

At the present time, however, the theoretical aspect of the subject is dealt with almost entirely from the calculator's point of view, and the average foreman is unable to grasp the reasoning owing to lack of simplicity in the explanations given. It will be obvious that some theoretical training is necessary in the case of the man who is in charge of the actual manufacture of a material which is designed on scientific lines, and more especially when the manufacture is carried out under difficult conditions by unskilled or semi-skilled workers. It is not always possible for the designer to be in constant touch with the actual execution of the reinforced concrete work which has been calculated and drawn up by him personally or under his direct supervision. Considerable influence on the success of the work must therefore be exercised by the responsible men on the site. To ensure a correct interpretation of the drawings and a faithful execution of the work it is necessary for the foreman to have some understanding of the designer's objects, thus calling forth a sense of responsibility which will invariably mean increased interest and closer attention to detail.

During the execution of a large scheme where reinforced concrete was extensively employed the author found some difficulty in getting certain bars placed in the correct positions; there was, in fact, a tendency to leave them out altogether at the commencement of the work, and the foreman did not appear to realise the importance of the matter although he had been previously engaged on reinforced concrete work. The author explained to the foreman, in simple language, the function of the bars, and gave an idea of the loads to be carried and the possible causes of failure, and appealed to the foreman's sense of responsibility as an aid in getting the work correctly and satisfactorily executed. The appeal was not in vain. The foreman's interest was awakened, and he felt the responsibility of carrying out the work conscientiously to ensure a safe structure. During the course of the job he approached the author on several occasions and asked for explanations in connection with several portions of the building. These being readily given, the interest was sustained, and the designer was able to feel that the man on the site was really cooperating with him in the execution of the work.

In these notes an endeavour will be made to give some useful information in simple language which will be readily understood by a practical man, and thus enable him to appreciate the necessity for carrying out the work in the best possible manner. In order to do this it is necessary to assume that the reader knows absolutely nothing about even the elementary principles, because any other assumption might possibly lead to an explanation which commenced at a stage beyond the reader's present knowledge and difficulties would then arise.

The importance of good work cannot

be emphasised too strongly, because it is quite impossible to judge the quality and accuracy of reinforced concrete construction after it is completed, and defective work may lead to failure having serious consequences which must necessarily spoil the reputation of the foreman in charge of the work, in addition to that of the persons in control of the scheme and to whom he is directly responsible. Defective work cannot be " patched up " if the construction is unsound, and the very nature of the work demands the rigid observance of the specification and drawings issued to the contractor for use on the site.

The older types of construction usually provided an excess of strength over that actually required to carry the loads owing to the fact that full advantage could not be taken of the natural resistance of some part of the materials employed on account of the manner in which they were applied, and in consequence a small error in execution was not likely to prejudice the safety of the structure to the same extent as is the case with reinforced concrete. Again, in the use of ordinary constructional steelwork it was necessary to work to standard sizes, and designers invariably had to select a section which was slightly stronger than that theoretically necessary ; thus the factor of safety was increased and there was a margin for error which would minimise the risk of failure in the structure.

These remarks are not intended to imply that errors are permissible in any kind of construction, or that great care should not be exercised in the execution of any type of work, but they are given to illustrate the necessity for extra care in work which provides no margin for errors, and in which all the materials are called upon actually to assist in carrying the loads.

Another point which must not be overlooked is that the parts used to build up a structure in the older types of construction are always manufactured in the shop or yard under conditions where control and standardisation make it possible to produce articles of a uniform quality, with the opportunity of inspection and testing before the units so produced are applied to a building, but in the case of reinforced concrete the whole of the parts, which together form the homogeneous structure, are manufactured on the site, and control and standardisation of methods are extremely difficult with the point of manufacture in its final stages continually changing from one position to another. The execution of the work is also continually passing across and over the portions of the structure previously manufactured, and in this respect the conditions of site work are totally different from those prevailing in the yard or shop. The foreman has to contend with numerous difficulties, and as no two schemes are exactly alike a continual call is being made on his organising ability and resources generally in order to achieve the aim which must guide his efforts if he is to be successful in his calling, viz. "to execute good and accurate work at the minimum cost."

The comparatively high cost of building and the natural disadvantages generally of the older methods of construction led to the development of reinforced concrete on a large scale, as the essential features of this type of construction are economy, adaptability, fire-resistance, durability, and suitability for practically all classes of structure.

The economy is achieved by the application of the materials in a scientific manner which takes advantage of their ability to offer resistance to a particular kind of stress, and each unit and each part of a unit is arranged in the position which will enable it to develop this resistance to the maximum amount.

It will be obvious that considerable calculations will be required for many parts of a reinforced concrete building before the designer can determine the exact amount and disposition of the steel and concrete to be employed, and during these calculations he will be working to several places of decimals in order to arrive at the exact theoretical requirements. Unless the work is executed with care and accuracy these calculations will be practically wasted, because the actual strength of the structure will not bear the correct relation to the theoretical strength ; in fact, the actual strength will be an unknown factor unless a physical test is made after the work is complete to determine what load is required to cause failure.

Reinforced concrete is constructed with two materials, viz. concrete and steel, and, as implied by the name, the structure is made of concrete reinforced by steel rods or bars. The question that naturally arises is, "Why is it necessary to reinforce concrete, which is a strong material itself and capable of carrying enormous loads?" The necessity is brought about by the fact that concrete is a strong material under compression but it is not capable of offering any appreciable resistance to tension, and the steel is introduced to give a resultant material which is strong both in compression and tension.

TERMS IN USE.

It is advisable to give here a simple definition of compression and tension, together with some of the other terms frequently used in order that the reader may be able to follow clearly the explanations given later.

STRAIN.

The terms "strain" and "stress" are frequently met with in dealing with the theory of reinforced concrete, but the reader is seldom given sufficient detail to show the difference between the two.

Strain is the distortion or alteration in shape produced by a force, load, or action which calls forth the resistance in a body. It does not necessarily mean an injury to the material or body, as the removal of the force may result in the distortion disappearing; the body would then have resumed its original shape and no injury would have been done.

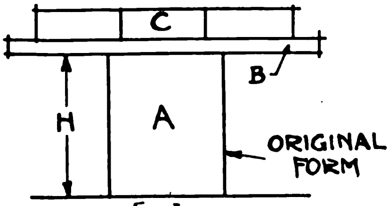


Fig I

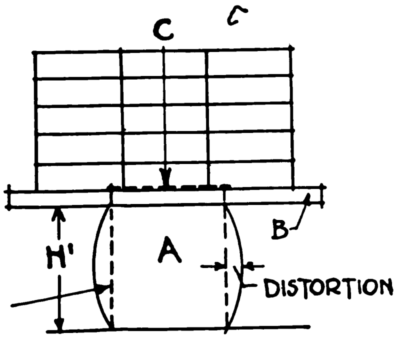


Fig. 2

A simple example of strain is that illustrated in *Figs.* 1 and 2, where (A) indicates a block of rubber, (B) is a plank or board, and (C) represents a pile of bricks, pig iron, or any other weight. The block in *Fig.* 1 is shown in its original form, but the action of the load pressing downward, when this load is sufficient, will cause the rubber block to bulge out on all four sides as shown in *Fig.* 2. At the same time the height shown at (H) in *Fig.* 1 will be reduced as shown at (H^1) in *Fig.* 2. In other words, the body of rubber has become distorted or altered in shape, and this distortion represents the strain. Upon the removal of the weight the rubber will recover its original form, and no injury has therefore been done to the material. The example given is one which can be easily tested by the reader by pressing his pencil down on to an ordinary piece of rubber eraser, and it is given on account of its simplicity.

The strain will be so minute in the case of strong materials and light loads as to be quite invisible to the naked eye, and the strain is therefore not generally obvious in ordinary building structures when loaded, but this does not necessarily mean that no strain exists.

The explanation of stress requires more consideration, as stresses are of different kinds and it is somewhat difficult to give a simple definition in a few words. As explained above, when a load or a force is applied to a piece of material it produces a strain or an alteration in the shape, and this calls forth a resistance in the material itself, which means that the material is subject to a stress. If we look up the dictionary we see that "stress" is defined as "force," and the definition of "force" is "strength," which indicates that stress and strength are allied. In other words, the strength or resistance of the material which comes into action under a load or force causes the stress to occur. If it were possible to obtain a material without any strength whatever it would be impossible to cause a stress in this material, as no resistance could be called forth. Again, it is impossible to cause stress in a material beyond its ultimate or maximum strength, because when the ultimate strength is reached the material will fail, resistance will end, and stress consequently disappears.

The amount of the stress will obviously be dependent on the force which the material has to resist, because the resistance will be dormant until it is brought into activity by the force applied. When the force is removed the stress will disappear, although the resistance remains, unless partial or complete failure has been caused, as will be mentioned later. To summarise this explanation it may be stated that "a stress in a material is caused by the resistance offered by this material to a force acting upon it."

The kinds of stress that require to be considered in reinforced concrete work generally are,

(*a*) tension,
(*b*) compression, and
(*c*) shearing.

Other kinds of stress are transverse, bearing, and torsional, but these need not be dealt with here in detail because, (1) a transverse stress is one which gives both tension and compression stress and is not so much a distinct stress as a condition of causing stress, (2) bearing stress is one which occurs when one body presses against another as in riveted steelwork, and (3) torsion is the stress caused by twisting the parts of a body in opposite directions, and although quite common in machinery is not met with in ordinary building work.

TENSION.

Tension stress is that caused by stretching a material, and a simple example of this may be given as that of taking an elastic band and stretching it out gently with the hands. The elastic will then be subject to a tensional stress caused by the force applied by the hands and the resistance of the material which is opposing the stretching action, and when the band is released it will contract back to its original shape. In a tug-of-war contest between two teams of men the rope used will be subject to tension stress. Any force which tends to lengthen a material or draw it out will result in tensional stress, and if the material fails it will do so by tearing.

Two simple diagrams are given in *Figs*. 3 and 4, which show a bar or piece of material which is being pulled or stretched at both ends, causing a tensional stress. *Fig*. 3 shows the original bar, and *Fig*. 4 indicates the tendency for the material to become longer and smaller in cross section until it is torn apart owing to the resistance of the material having been overcome. Although the material may not become appreciably longer, and although it may not be torn apart owing to the force not being sufficient to cause these effects, the tendency is there nevertheless, and a state of tensional stress exists.

In a simple reinforced concrete beam the resistance to tension is provided by the steel rods, as the concrete is unable to withstand any appreciable pulling or tearing force. The position and amount of steel required and other points in connection with the resistance to tension will be dealt with later, as we are at present dealing with the explanation of terms in use only and it is necessary for the reader to understand thoroughly the terms before considering in any way their application.

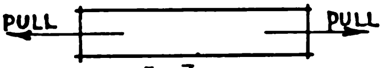


FIG. 3

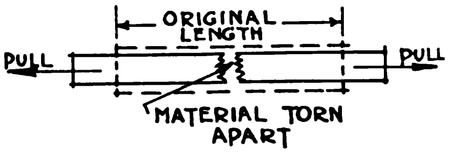


FIG 4

COMPRESSION.

The second kind of stress mentioned is compression. This can be considered as directly opposite to tension, because it is the stress caused when a material is under the action of a load or force which is tending to compress or shorten it. When the material fails it does so by crushing, unless the material is in the form of a long member which will bend under the compression, as mentioned later.

A very simple example of compression is that of crushing a walnut with a pair of ordinary nut-crackers, as the pressure on the crackers causes compression stress on the nut and if the pressure is maintained the nut will fail by crushing. An illustration of a block under a load is shown in *Fig*. 5, and the result of the load when the material fails through compression stress is indicated in *Fig*. 6.

It will be understood that the effect of compression sufficient to cause failure will be different in different materials, as, for example, the failure in timber will depend on the condition of loading—whether across the grain or in the direction of the length of the grain—while in the case of concrete the crushing of the material will give a failure which will look very different from that given in the case of a piece of steel.

Generally speaking, the material will bulge out on all sides. In the case of concrete cubes which are subjected to compression until failure occurs, the sides will fall away somewhat as shown by the dotted lines (C) in *Fig.* 6 if the material is of the normal kind. It will be seen that the failure is due to a bursting outward, and it is important for the reader to remember this point as it will be referred to again in connection with reinforced concrete columns.

In a simple reinforced concrete beam the compression resistance is provided by the concrete, and this will be dealt with in detail later.

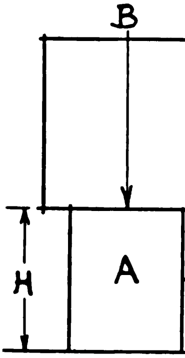


Fig 5

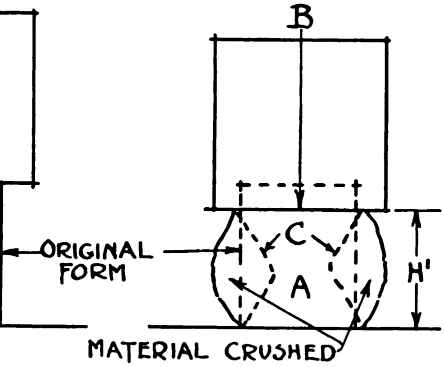


Fig. 6

SHEARING.

The third and last kind of stress mentioned to be dealt with in detail is that of shearing. This stress can be defined as a cutting or sliding one, and when failure occurs the material is separated into two or more portions by the sliding of one section, either horizontally or vertically, away from the adjoining section. The action of cutting a piece of paper with a pair of scissors is a shearing action, and if a brick is pushed off the top of a pier or wall while the joint is soft, causing it to slide on its bed and overcome the resistance of the mortar, then the brick is displaced through shear.

Some simple illustrations are given in *Figs.* 7 to 12, which indicate horizontal and vertical shear in a manner which can be tested by the reader. *Fig.* 7 shows two bricks placed together with a weak mortar, and the arrows marked (A) indicate pressure applied at one end of each brick in opposite directions. When the pressure is sufficient to overcome the joint the two bricks will slide apart as shown in *Fig.* 8, and the joint will have failed under horizontal shearing stress.

Again, in *Fig.* 9 some blocks are shown at (B), and these are connected by small soft-wood dowels at each joint shown at (C). The blocks can be held together by a small cramp, or even by hand, and if the force is applied by striking the blocks with a hammer the dowels will fail by shear and the blocks will tend to slide downward as indicated in *Fig.* 10.

Another simple illustration is that of placing some thin planks on top of one another with a support at each end, as shown in *Fig.* 11, and then placing a load in the centre of the span as at (A), this load being sufficient to bend all the planks downward as indicated in *Fig.* 12. It will then be found that the ends of the planks no longer coincide as they did before the load was applied, because the bottom edge at the end of each plank has slid outward and projects beyond the top edge of the plank below. This sliding action is due to the horizontal shearing action which overcomes the friction hold between each plank.

In all these examples of shear separate units have been shown, and the reader may consider that there would be some difference in the stresses if the loads or forces were applied to a portion of a complete reinforced concrete structure owing to the absence of joints on the latter.

These examples are, however, given to illustrate what is meant by the different kinds of stress and the nature of each stress. The stress will exist in the portion of a complete structure, and the *tendency* to fail will occur irrespective of the shape or material used. This tendency to fail must be overcome by the strength of the structure, and each part of the structure must be designed and constructed to prevent complete or partial rupture in any of the ways described.

To summarise these stresses, which are the kind met with in ordinary building work, we have,

(1) Tension, which is a stretching or tearing stress,

(2) Compression, which is a shortening or crushing stress, and,

(3) Shearing, which is a cutting or sliding stress.

It must be borne in mind that the whole object of these notes is to convey the information in as simple a manner as possible to enable the reader to understand fully each term used, and it is therefore difficult in some cases to adhere to expressions which are strictly correct from the technical standpoint. It is far easier to express a technical matter in technical language, but this would merely be repeating matter which is available in several excellent textbooks on the subject of reinforced concrete design.

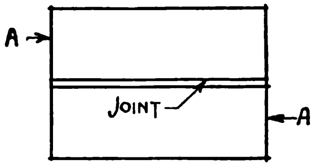


Fig. 7

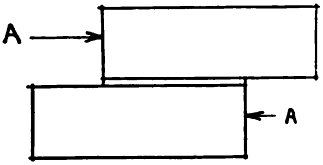


Fig. 8

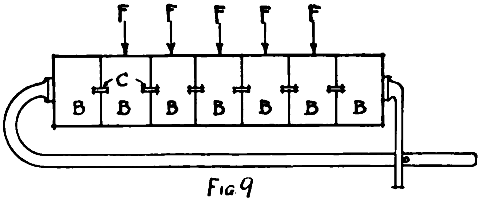


Fig. 9

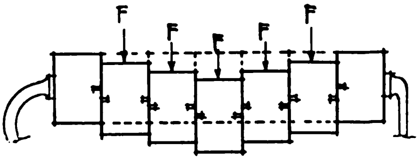


Fig. 10

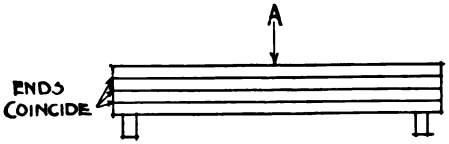


Fig. 11

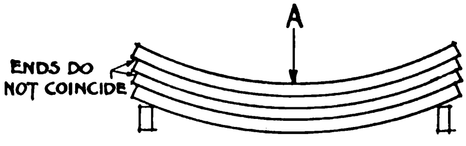


Fig. 12

(*To be continued.*)

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ½ in. mesh	,,	15	0
Best British Portland Cement	per ton 58s. to	63	0
"Ferrocrete" Portland Cement	10s. per ton extra		

Boarding for Shuttering—

		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £24 10s. per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £25 10s. ,, ,,

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
9/16 in. to ½ in. Rounds	,,	13	6
⅜ in. Rounds	,,	14	6
¼ in. Rounds	,,	15	6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed with Clean Water in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per yard cube	48	0
Do.	do.	in columns	,, ,,	53	0
Do.	do.	in beams	,, ,,	53	0
Do.	do.	in floor slabs 4 in. thick	per yard super	5	7
Do.	do.	in floor slabs 6 in. thick	,, ,,	8	4
Do.	do.	in floor slabs 9 in. thick	,, ,,	12	1
Do.	do.	in walls 6 in. thick	,, ,,	8	7

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	24	0
,, 9/16 in. to ½ in.	,,	23	0
,, ⅝ in. to 2⅞ in.	,,	22	0

EXTRA LABOUR TO BENDS in ¼-in. rods, ½d.; ⅜-in. rods, 1d.; ½-in. rods, 1¼d.; ⅝-in. rods, 1½d.; ¾-in. rods, 1¾d.; ⅞-in. rods, 2d.; 1-in. rods, 2¼d.; 1⅛-in. rods, 3d.; 1¼-in. rods, 3½d.

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1d.; ⅜ in., 2d.; ½ in., 2½d.; ⅝ in., 3d.; ¾ in., 3½d.; ⅞ in., 4d.; 1 in., 4½d.; 1⅛ in., 6d.; 1¼ in., 7d.

Shuttering—

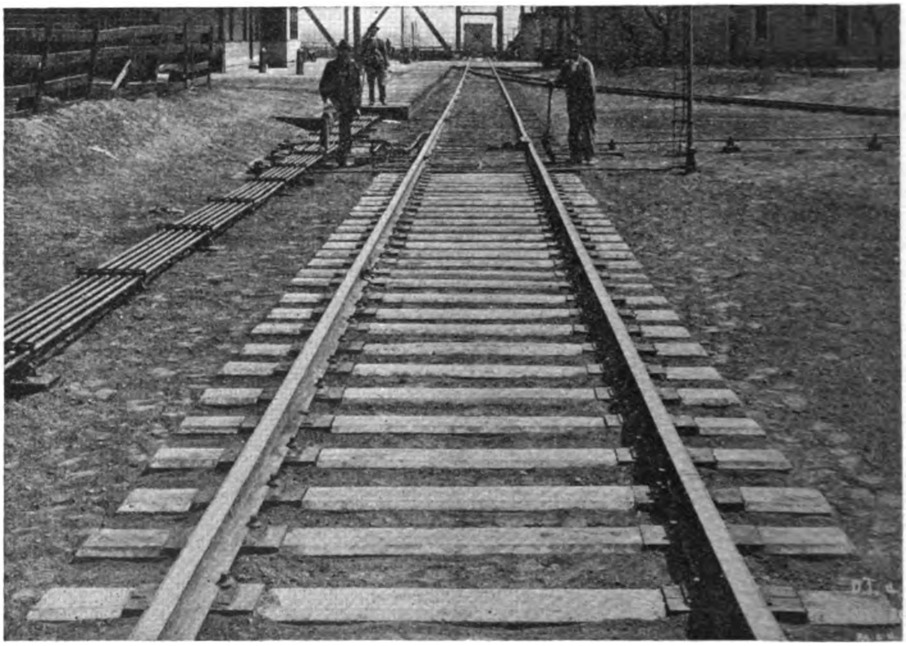
		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	57	6
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	53	6
Do. do. in small quantities	per ft. super	0	9½
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last, in narrow widths	,, ,,	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	,, ,,	1	1
Do. do. as last, in narrow widths	,, ,,	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/8½ per hour; Labourers on building works, 1/3½; Operators on concrete mixers and hoists, 1/4½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

NEW CONCRETE RAILWAY SLEEPER.

A NEW concrete railway sleeper has recently been tested on the Detroit, Toledo, and Ironton Railway in the United States which is designed to give the resiliency of a wood tie and yet at the same time to be indestructible. Resiliency is provided for in the concrete sleeper by wooden blocks which are fitted into a prismatic opening on the upper side of each end of the sleeper and bound by bolted clamps. The rails are spiked to these blocks. The concrete sleeper is set into the road bed about 9 in. deep so that its top comes almost flush with the ballast. The sleeper has an arch on the underside which prevents it from moving from side to side, and which gives it a uniform bearing throughout its entire length. The sleeper is heavily reinforced with steel rods. This sleeper which was invented by Fred C. Shearer, Bloomington, Illinois, has been tested for three years in switch yards at Dallas, Texas, U.S.A.



NEW TYPE OF CONCRETE RAILWAY SLEEPER.

TRANSPORTING CEMENT.

CONSIDERABLE interest is being taken in Germany in the use of closed steel tank wagons for the transport of Portland cement. These wagons closely resemble those used for petroleum, and consist of a horizontal steel cylinder, with slightly rounded ends, mounted on suitable wheel-base. They are filled from a silo through hatchways in the top of the cylinder, care being taken to provide additional openings through which the air in the cylinder may escape. When the hatchways are closed the cement cannot become spoiled by air or water.

The tanks are emptied by attaching two pipes, one for admitting air under pressure ; and the second, which is larger, being the outlet for the cement and blowing the cement into a closed silo. If desired, the tanks may be filled by suction, this method being particularly convenient when discharging a shipload of cement.

The power required is said to be only ½ h.p. per ton per hour, so that the cost is far less than the use of bags when large quantities of cement have to be transported. This method of conveying cement is obviously limited in its application, but where it can be used it has much to commend it.

PROSPECTIVE NEW CONCRETE WORK.

ACCRINGTON.—*Houses.*—The Housing Committee proposes to erect 103 houses at Laneside Farm.

ANNFIELD PLAIN.—*Road.*—The U.D.C. has applied for sanction to borrow money for the construction of a road across Mountsett Fell.

BARMOUTH.—*Bridge.*—The U.D.C. and the G.W.R. Co. are considering a scheme for the erection of a bridge over the railway at Barmouth.

BARNSLEY. — *Concrete Houses.* — The T.C. proposes to erect 120 concrete houses.

BARNSLEY.—*Footpaths.*—The T.C. proposes to construct concrete footpaths, at an estimated cost of £5,366.

BIRKENHEAD.—*Houses.*—The Corporation has applied for sanction to borrow £87,162 for the construction of 193 houses.

BLAYDON.—*Houses.*—The U.D.C. has applied to the M.H. for permission to erect 50 houses.

BOLSOVER.—*Houses.*—The U.D.C. has applied for sanction to borrow £14,000 in connection with the construction of 30 houses.

BOLTON.—*Tar Well.*—The T.C. has sanctioned a loan of £6,400 for the construction of a reinforced concrete tar well.

BURNHAM-ON-SEA. — *Houses.* — The U.D.C. proposes to erect 40 houses.

CARDWELL.—*Jetty.*—The Council proposes to borrow £80,000 for the erection of a jetty at Oyster Point.

CASTLE HEDINGHAM.—*Reservoir.*—The Parish Council proposes to construct a concrete reservoir with a capacity of 16,000 gallons.

COLWYN BAY.—*Houses.*—The U.D.C. is considering the question of erecting 175 houses on the Tan Lan estate.

DARLINGTON. — *Sewerage Works.*—The Corporation has applied for sanction to borrow £1,150 for alterations to the sewerage works.

FARNHAM (SURREY).—*Concrete Houses.*—The Housing Committee has applied to the M.H. for sanction to borrow £5,600 in connection with the construction of 10 concrete houses.

GATESHEAD.—*Houses.*—The T.C. proposes to apply to the M.H. for sanction to borrow £50,000 in connection with the building of 100 houses at Carr Hill.

GREENOCK.—*Road.*—The Corporation proposes to construct a road to provide a direct thoroughfare to Inverkip Road, at an estimated cost of £30,000.

GRINDLETON.—*Bridge.*—The Clitheroe R.D.C. and Bowland R.D.C. are considering a scheme for the construction of a bridge over the Ribble, estimated to cost £8,000.

HENSTEAD. — *Concrete Houses.* — The R.D.C. is considering the question of erecting concrete houses.

HINDLEY. — *Sewerage Works.* — The R.D.C. has applied to the M.H. for sanction to borrow £13,000 for the construction of sewage disposal works.

KNARESBOROUGH. — *Paving.* — The U.D.C. proposes to reconstruct the Market Place in concrete.

MIDSOMER NORTON.—*Sewerage Works.*—The U.D.C. has applied to the M.H. for sanction to construct sewage disposal works at Old Welton.

NEWRY.—*Houses.*—The U.D.C. has a scheme in hand for the construction of 42 houses.

NOTTINGHAM.—*Road.*—The T.C. has under consideration a scheme for the construction of a road from Basford to Bulwell.

OTLEY.—*Road.*—The U.D.C. has submitted to the Unemployed Grants Committee a proposal for the construction of a road from Leeds Road to Ilkley Road.

OUGHTIBRIDGE.—*Houses.*—The Wortley R.D.C. proposes to build 20 houses.

PONTYPRIDD.—*Road.*—The Rhondda U.D.C. and Pontypridd U.D.C. are considering a scheme for the construction of a road, estimated to cost £50,000.

PORTSMOUTH.—*Steps.*—The T.C. proposes to spend £575 on the construction of concrete steps on the esplanade.

ROYSTON. — *Bridge.* — The U.D.C. is considering the question of constructing a bridge over the canal.

ST. HELENS.—*Houses.*—The Corporation Housing Committee has applied for sanction to borrow £43,000 for the construction of 60 steel and concrete houses.

SEATON DELAVAL. — *Houses.* — The U.D.C. proposes to erect 150 houses.

SELBY. — *Bridge.* — The West Riding C.C. proposes to construct a bridge over the Selby Canal to replace the stone bridge at Carlton Road.

SHEFFIELD.—*Houses.*—The Corporation proposes to construct 300 houses, at an estimated cost of £154,105.

TENDERS ACCEPTED.

BALLYMONEY—*Concrete Houses.*—The U.D.C. has accepted the tender of Mr. W. Currie, Coleraine, at £9,530, for the erection of 22 concrete houses.

BARNSLEY.—*Concrete Houses.* — The T.C. has accepted the tender of the U.K.H. Syndicate, Ltd., at £670 per pair, for the erection of 50 concrete houses.

BOOTLE.—*Flags.*—The Corporation has accepted the tender of Mr. A. H. Evans, Liverpool, for the supply of 1,750 sq. yds. of concrete flags, at 5*s*. 6*d*. per sq. yd.

BOOTLE.—*Flags.*—The Corporation has accepted the tender of the Liverpool Artificial Stone Co., at 5*s*. 6*d*. per sq. yd., for the supply of 1,750 sq. yds. of concrete flags.

BOURNEMOUTH.—*Pierhead.*—The T.C. has accepted the tender of Messrs. Frank Bevis, Ltd., at £10,250, for reconstructing Boscombe pierhead in reinforced concrete.

BRICKLOW.—*Sewerage Works.* — The R.D.C. has accepted the tender of Messrs. G. D. Hayes & Son, Stockport, for the construction of the Mobberley sewage disposal works.

BRIDLINGTON.—*Reservoir Cover.*—The Corporation has accepted the tender of Messrs. Squires & Sons, Selby, at £4,208 8*s*., for the construction of a reinforced concrete cover to the reservoir.

CARLISLE.—*Foundations.*—The T.C. has accepted the tender of Messrs. Morgan & Cleghorn, Ltd., Newcastle-upon-Tyne, at £1,386, for foundation work for the new generating station.

CLEOBURY MORTIMER.—*Wall.* — The R.D.C. has accepted the tender of Mr. S. W. Hall for the construction of a concrete wall.

LEICESTER.—*Concrete Houses.* — The Housing Committee has recommended for acceptance the tender of Messrs. H. Boot & Co., at £735,000, for the construction of 1,500 concrete houses.

LONDON.—*Floors.*—The Metropolitan Asylums Board has accepted the tender of Messrs. C. H. Boyd and Son, Ltd., 37 Craven Terrace, W.C.2., at £972. for the construction of reinforced concrete floors.

LONDON.—*Floors.*—The Metropolitan Asylums Board has accepted the tender of Messrs. Baker & Sons, at £1,192, for the construction of reinforced concrete floors.

LONDON.—*Paving.*—The Metropolitan Asylums Board has accepted the tender of Mr. W. Simms, at £175, for the laying of concrete paving.

PERSHORE (WORCS.).—*Bridge.* — The Worcestershire C.C. has accepted a tender, at £15,859, for the construction of a reinforced concrete bridge over the Avon at Pershore.

TAUNTON.—*Tank.*—The T.C. has accepted the tender of Messrs. F. & E. Small, at £350, for the construction of a concrete screening tank at Coal Orchard.

THURUSCOE (Yorks.).—*Reservoir.*—The U.D.C. has accepted the tender of Messrs. G. Bell & Sons, Ltd., Tottenham, London, at £6,840, for the construction of a covered concrete reservoir, with a capacity of 600,000 gallons.

RECENT PATENT APPLICATIONS.

203,308.—Raymond Concrete Pile Co.: Composite piles.

211,121.—G. Grimaad: Reinforced concrete stakes.

214,633.—T. L. Smith & Co.: Concrete mixing machines.

219,169.—F. H. Jones: Concrete beams and slabs for floors, roofs and ceilings.

219,482.—B. Talbot: Coating of iron or steel with concrete or pitch.

219,519.—A. E. White (Raymond Concrete Pile Co.): Pile drivers.

219,759.—J. Ferneyhough: Construction of iron or steel reinforcement for concrete floor slabs.

219,859.—H. H. Blanchford: Means for use in making walls and other structures of concrete.

220,106.—R. H. Rogers: Concrete structures.

220,204.—R. H. Rogers: Movable shuttering for use in concrete constructional work.

220,242.—E. Ligonnett: Wire reinforcement for pipes and similar articles of cement.

TRADE NOTE.

A NEW catalogue (List 5) of their well-known series of books on civil engineering has been issued by the McGraw-Hill Publishing Co., Ltd., of 6 Bouverie Street, London, E.C.4.

Price 1*s*. 6*d*. *net*. *Annual*, *Post Free*, 18*s*.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

NOVEMBER 1924 VOL. XIX No. 11

NINETEENTH YEAR OF PUBLICATION

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Data for Pricing Reinforced Concrete Work.

Prospective New Concrete Work.

Tenders Accepted.

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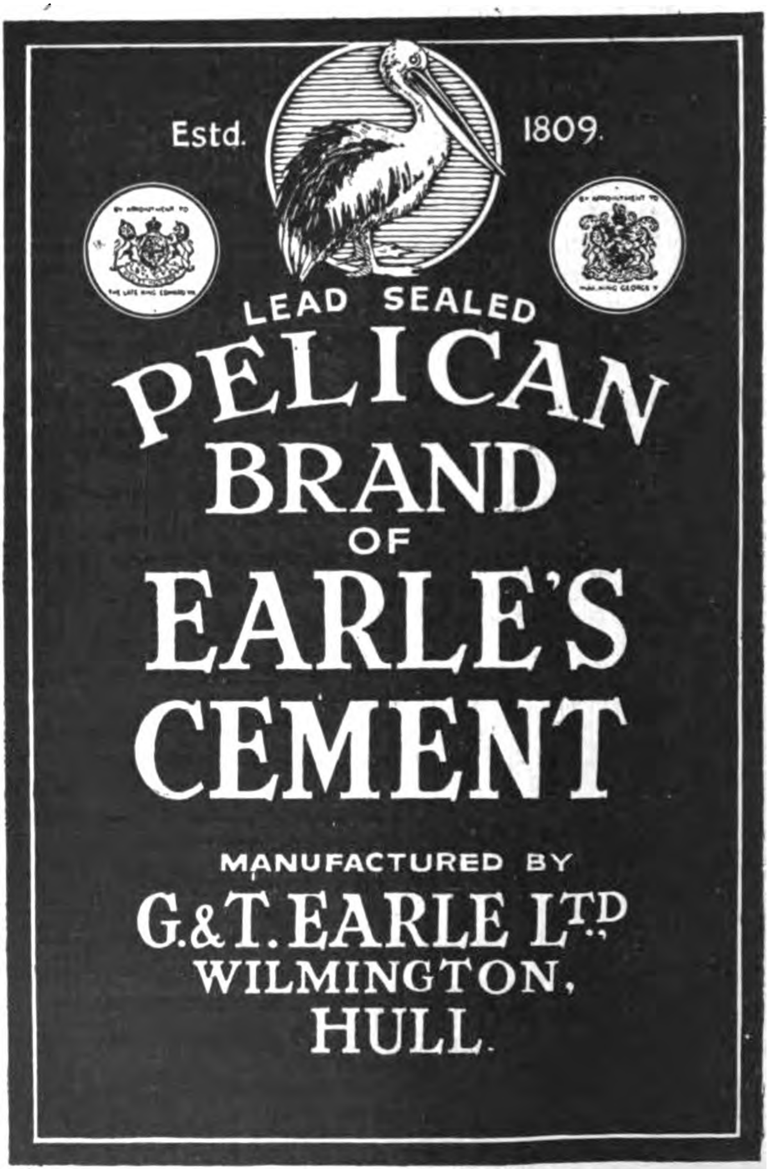

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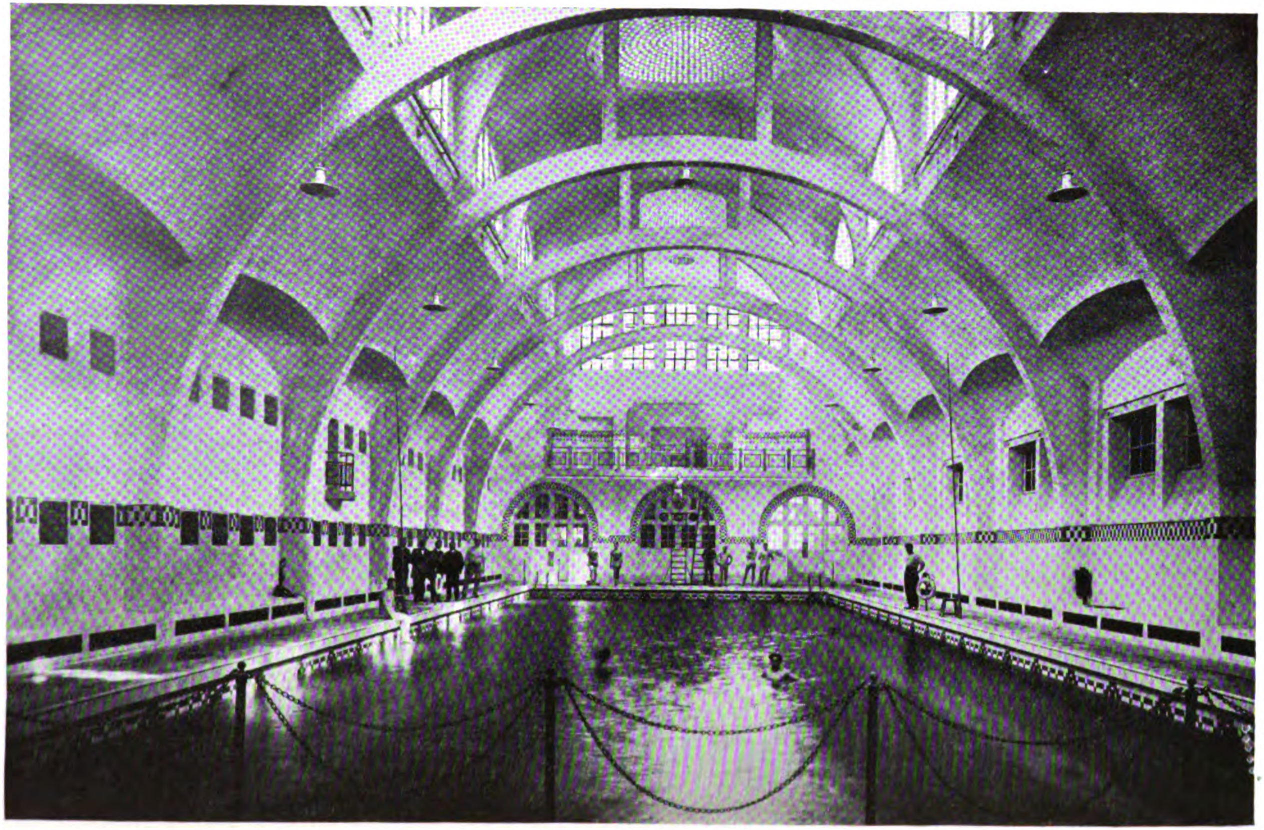

REINFORCED CONCRETE SWIMMING BATH AT PARIS. (*See p.* 697.)

CONCRETE
AND
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Volume XIX. No. 11. LONDON, NOVEMBER, 1924.

EDITORIAL NOTES.

PROPORTIONING CONCRETE.

THE necessity for the proper proportioning of aggregates if the strongest and at the same time the cheapest concrete is to be obtained is generally realised, and a great deal of research and experimental work has been carried out to determine what proportions of graded coarse aggregate, sand, cement and water give the best results for different purposes. An exhaustive series of tests on the subject was undertaken two years ago by Professor Duff Abrams and Mr. Stanton Walker at the Structural Materials Research Laboratory of the Lewis Institute, Chicago, as a result of which tables were prepared showing the proportioning necessary to produce concretes of different compressive strengths ranging from 1,500 lb. per sq. in. to 4,000 lb. per sq. in. These tables were given in our issues for October and November, 1922.

The tables are based on what is called the " fineness modulus " method of proportioning, *i.e.* beginning with a 100-mesh sieve and doubling the size of the opening for each succeeding sieve, the percentages of the material retained on each sieve are added together, and a coefficient is obtained which indicates the concrete-making quality of the aggregate. To reduce this coefficient to significant figures the sum of the percentages coarser than each sieve is divided by 100, and the resultant figure called the " fineness modulus." With the aid of the tables and an analysis of the aggregate with a set of sieves, it is thus an easy matter to determine the volume of fine sand, coarse aggregate and cement which will give a definite strength at 28 days.

An interesting account has just come to hand of the application of the " fineness modulus " method of proportioning and the tables to concrete road construction by Mr. P. E. Kressly in California, which clearly indicates the practicability of the system, tests showing that the variation from the strength aimed at was only 7·1 per cent. compared with a variation of 15 per cent. in the case of concrete proportioned by " the best of the old methods." " The use of this modern method of proportioning," it is stated, " was not nearly so intricate as is often supposed. It produces concrete far superior to that possible with the former hit-and-miss method, and effects economies by permitting the use of local materials of a size which would be improper under the old specifications." We have heard of no instance where this method of proportioning has been put into practice in this country, but it would seem that there must be many works in which it could be used with advantage.

SCIENTIFIC AND INDUSTRIAL RESEARCH.

THE Government Department of Scientific and Industrial Research has published its report for the year 1923-24, and a study of its pages leads to the conclusion that, given wise direction and ample funds, this Department is capable of rendering services of incalculable benefit to the nation. One can indeed foresee that in a more enlightened age some of the millions now spent upon the combatant forces will be diverted for the use of such a body as this, so that the nation may enjoy the advantages that cannot fail to accrue from the scientific investigation of problems connected with the prosperity, comfort, and physical well-being of the population.

The Building Research Board forms only a small part of the activities of the Research Department, yet it alone in its investigations on building materials has for one of its aims the development of cheap and reliable methods of house construction, and the successful issue of these investigations would go far to solve the housing problem which is so closely connected with the health and comfort of a large proportion of the people. When it is realised that the scientific work of the Department deals with such diverse subjects as the packing of food stuffs, domestic heating, pollution of the atmosphere, corrosion of metals, and " wireless " it is impossible to do other than wish the utmost success to the Department.

The operations of the Department are broadly speaking conducted in two ways ; first, by subsidising industrial research associations ; and second, by direct employment of research workers. The British Portland Cement Research Association is an example of the first method. This Association has for its members the majority of the cement manufacturers in the United Kingdom, and a Council elected by the members directs the work of chemists and engineers in investigations designed to lead to the cheapening of production and improvement of quality of Portland cement. The work of the British Portland Cement Research Association is, in fact, almost exclusively confined to the manufacture of cement, and the results of research are intended primarily for the use of the members only and usually are not published.

The Building Research Board is an example of the second method, by which the Research Department operates. The Board and its three Committees are composed of a number of experts in various departments of constructional work and have technical investigators working under their direction. We give on another page extracts from the Research Department's report giving some indications of the nature of the investigations now in hand. In this case the results of research are published in pamphlets or in various scientific journals, all available to the public. Our extracts show that the Building Research Board fully recognises the importance of concrete as a building material, because more than half the investigations mentioned in the report are connected with concrete and cement. It is satisfactory to note that there is a proposal to continue the work of the Building Research Board for a further five years, and we hope it will be possible to increase the allowance for expenditure beyond the sum of £8,960 which was spent last year.

INFLUENCE LINE DIAGRAMS FOR SHEARING FORCE, BENDING MOMENT, SLOPE, AND DEFLECTION FOR SINGLE-SPAN GIRDERS.

By W. NORMAN THOMAS, M.A., D.Phil., M.Sc., A.M.Inst.C.E.

AN influence line diagram is constructed to show the values of such a quantity as shearing force, bending moment, slope, or deflection *at a definite point* in a beam for various positions of a concentrated unit load moving along the beam. Thus in *Fig.* 6 the ordinate DD_1 represents the bending moment at the point X (that being the point for which this particular influence line is drawn) when unit concentrated load is applied at the point D.

From the influence line diagrams for a concentrated unit load, the effect of a distributed load or of a series of concentrated loads may be studied, and " maximum " diagrams of shearing force, bending moment, slope, or deflection may be drawn for any particular type of loading.

But such applications are beyond the scope of the present paper, the object of which is to show how the influence lines themselves may be derived in the case of a simple beam

(*a*) Simply supported at its two ends, A and B.
(*b*) Encastered ,, ,, ,, ,,
(*c*) Encastered at one end (A) and supported at its other end (B).
(*d*) ,, ,, ,, (A) ,, unsupported ,, ,,

Most of these cases are not dealt with in the text-books.

Let X denote the point in the beam AB for which the influence lines are to be drawn, and let the distances AX, BX and AB be x, x_1, and l units respectively. Let the distances from A and B respectively, to the concentrated load, W, be a and b units.

We know that if the deflection at any point be y units

$$\text{the slope of the beam is } \frac{dy}{dx}$$

$$\text{the bending moment is } EI\,\frac{d^2y}{dx^2}$$

$$\text{and the shearing force is } EI\,.\,\frac{d^3y}{dx^3}$$

where E represents the modulus of elasticity of the beam material, and I represents the moment of inertia of the cross section of the beam about its neutral axis.

Considering a point at a distance x from A where $x<a$ (*Fig.* 1) the shearing force is equal to the reaction R_A, so that we have

$$E.I.\frac{d^3y}{dx^3} = R_A \quad . \quad . \quad . \quad . \quad . \quad (1)$$

By integrating this expression, it follows that

$$E.I.\frac{d^2y}{dx^2} = R_A.x + M_A \quad . \quad . \quad . \quad . \quad (2)$$

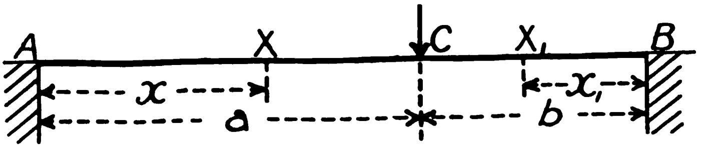


FIG. 1.

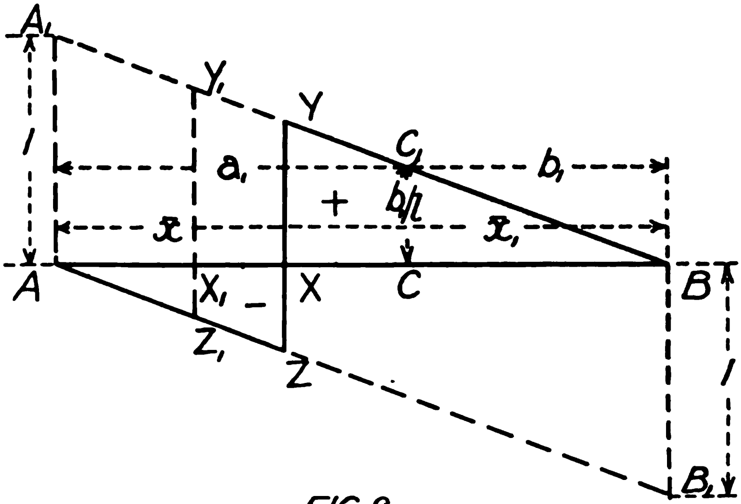


FIG. 2

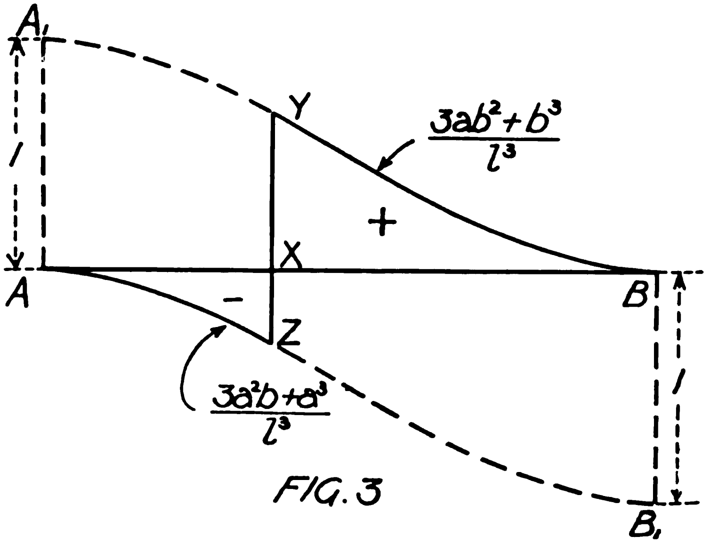


FIG. 3

where M_A is the bending moment at A; and similarly

$$EI\frac{dy}{dx} = R_A.\frac{x^2}{2} + M_A.x + K_1 \quad . \quad . \quad . \quad (3)$$

and

$$EIy = R_A\frac{x^3}{6} + M_A\frac{x^2}{2} + K_1x + K_2 \quad . \quad . \quad . \quad (4)$$

where K_1 and K_2 are constants of integration.

Similarly at a point x_1 from B where $x_1 < b$ (*Fig.* 1)

$$EI\frac{d^3y}{dx^3} = R_B \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1a),$$

$$EI\frac{d^2y}{dx^2} = R_B.x_1 + M_B \quad . \quad . \quad . \quad . \quad . \quad . \quad (2a)$$

$$EI\frac{dy}{dx} = R_B\frac{x_1^2}{2} + M_Bx_1 + K_3 \quad . \quad . \quad . \quad . \quad . \quad (3a)$$

$$EIy = R_B\frac{x_1^3}{6} + M_B\frac{x_1^2}{2} + K_3x_1 + K_4 \quad . \quad . \quad . \quad (4a)$$

There are thus 8 equations, and 8 unknowns to be found, i.e. R_A, R_B, M_A, M_B, K_1, K_2, K_3 and K_4, the values depending upon the end conditions at A and B.

(*a*) Simply Supported Beam.

The constants are easily obtained in this case, as obviously $R_A = \frac{Wb}{l}$, $R_B = \frac{Wa}{l}$, $M_A = 0$, $M_B = 0$.

Also as $y = o$ at A when $x = 0$, it follows from (4) that $K_2 = 0$
and ,, ,, B ,, $x_1 = 0$,, ,, (4*a*) ,, $K_4 = 0$.

The deflection at the point C, under the load, can be obtained by substituting $x = a$ in equation (4) or by substituting $x_1 = b$ in equation (4*a*).

The slope of the beam at the point C can be obtained by substituting $x = a$ in equation (3) or by substituting $x_1 = b$ in equation (3*a*), the sign being different in the two cases as x and x_1 are measured in opposite directions.

We can thus get two equations from which the two constants K_1 and K_3 may be determined.

i.e.

$$R_A\frac{a^3}{6} + M_A.\frac{a^2}{2} + K_1a + K_2 = R_B.\frac{b^3}{6} + M_B.\frac{b^2}{2} + K_3b + K_4 \quad . \quad (5)$$

from equations (4) and (4*a*),

and

$$R_A.\frac{a^2}{2} + M_Aa + K_1 = -\left(R_B\frac{b^2}{2} + M_Bb + K_3\right) \quad . \quad . \quad (6)$$

from equations (3) and (3*a*).

From the equations (5) and (6) it may be shown that

$$K_1 = -\frac{W.ab}{6l}(a + 2b)$$

$$K_3 = -\frac{Wab}{6l}(2a + b)$$

(*b*) Beam Encastered at A and B.

In this case the constants $K_1 = 0$ and $K_3 = 0$ as the inclination of the beam $\frac{dy}{dx} = 0$, both at A and at B, whatever the position of the load.

Similarly the constants $K_2 = 0$ and $K_4 = 0$ as $y = 0$ both at A and at B.

The remaining constants are not found so easily; R_A is not equal to $\frac{Wb}{l}$ as for a simply-supported beam, nor is $R_B = \frac{Wa}{l}$, unless either $a = b$, $a = 0$ or $b = 0$.

We know, however, that

$$R_A + R_B = W \qquad . \quad . \quad . \quad . \quad . \quad (7)$$

and by equating the two expressions for the B.M. at C from equations (2) and (2*a*)

$$R_A.a + M_A = R_B.b + M_B \qquad . \quad . \quad . \quad . \quad . \quad (8)$$

Two further equations may be obtained from (3) and (3*a*), and from (4) and (4*a*), as before, i.e.

$$R_A.\frac{a^2}{2} + M_A.a = -\left(R_B.\frac{b^2}{2} + M_B.b\right) \qquad . \quad . \quad . \quad (9)$$

and

$$R_A\frac{a^3}{6} + M_A\frac{a^2}{2} = R_B.\frac{b^3}{6} + M_B.\frac{b^2}{2} \qquad . \quad . \quad . \quad (10)$$

From these equations the constants may be determined, i.e.

$$R_A = \frac{3ab^2 + b^3}{l^3}.W.$$

$$R_B = \frac{3a^2b + a^3}{l^3}.W.$$

$$M_A = -\frac{ab^2}{l^2}.W.$$

$$M_B = -\frac{a^2b}{l^2}W.$$

(*c*) Beam Encastered at A and Supported at B.

In this case, as before, $K_1 = 0$, $K_2 = 0$, $K_4 = 0$, and also $M_B = 0$. The remaining constants are found from the equations

$$R_A + R_B = W. \qquad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

$$R_A.a + M_A = R_B.b \qquad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

$$R_A\frac{a^2}{2} + M_A.a = -\left(R_B\frac{b^2}{2} + K_3\right) \qquad . \quad . \quad . \quad (13)$$

$$R_A\frac{a^3}{6} + M_A\frac{a^2}{2} = R_B.\frac{b^3}{6} + K_3x \qquad . \quad . \quad . \quad . \quad (14)$$

and their values are

$$R_A = \frac{b(6ab + 3a^2 + 2b^2)}{2l^3}.W.$$

$$R_B = \frac{3a^2b + 2a^3}{2l^3}.W.$$

$$M_A = -\frac{ab(a + 2b)}{2l^2}W.$$

$$K_3 = -\frac{a^2b}{4l}.W.$$

(*d*) Cantilever Encastered at A and free at B.

Here $R_A = W, R_B = 0, M_A = - W.a., M_B = 0, K_1 = 0, K_2 = 0, K^3 = \frac{Wa^2}{2}$, $K_4 = \frac{Wa^3}{6} - \frac{Wa^2l}{2}$.

These results—substituting W = 1—may be tabulated as follows :—

CONSTANTS FOR A SINGLE-SPAN BEAM AB

	A supported B ,,	A encastered B ,,	A encastered B supported	A encastered B free
R_A	$\frac{b}{l}$	$\frac{3ab^2 + b^3}{l^3}$	$\frac{b(6ab + 3a^2 + 2b^2)}{2l^3}$	1
R_B	$\frac{a}{l}$	$\frac{3a^2b + a^3}{l^3}$	$\frac{3a^2b + 2a^3}{2l^3}$	0
M_A	0	$-\frac{ab^2}{l^2}$	$-\frac{ab(a + 2b)}{2l^2}$	$-a$
M_B	0	$-\frac{a^2b}{l^2}$	0	0
K_1	$-\frac{ab(a + 2b)}{6l}$	0	0	0
K_2	0	0	0	0
K_3	$-\frac{ab(2a + b)}{6l}$	0	$-\frac{a^2b}{4l}$	$\frac{a^2}{2}$
K_4	0	0	0	$\frac{a^3}{6} - \frac{a^2l}{2}$

INFLUENCE LINES FOR SHEARING FORCE.

(*a*) Simply Supported Beam.

When $x < a$ the shearing force is equal to the reaction R_A, and may be considered as positive (the sign is quite arbitrary), and when $x > a$ the shearing force is equal to the reaction R_B, and is negative in sign.

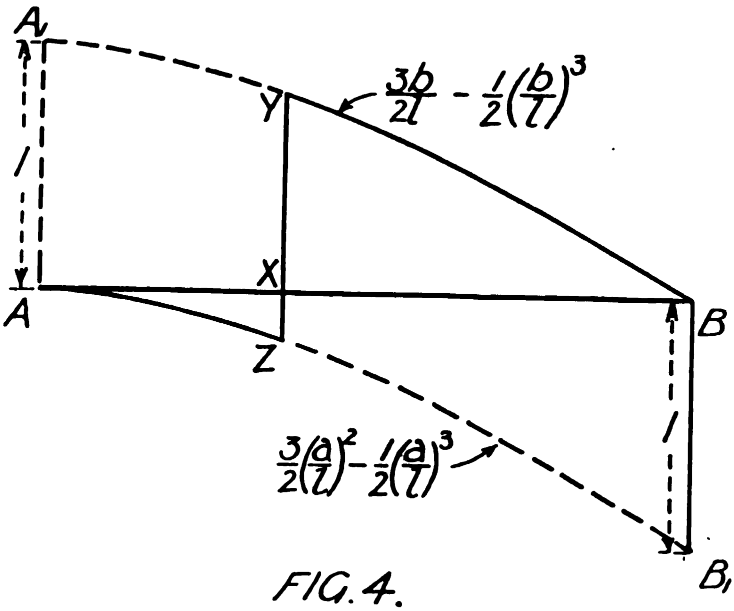

A_1
Y
$\frac{3b}{2l} - \frac{1}{2}\left(\frac{b}{l}\right)^3$
1
X
A
B
Z
1
$\frac{3}{2}\left(\frac{a}{l}\right)^2 - \frac{1}{2}\left(\frac{a}{l}\right)^3$
B_1

FIG. 4.

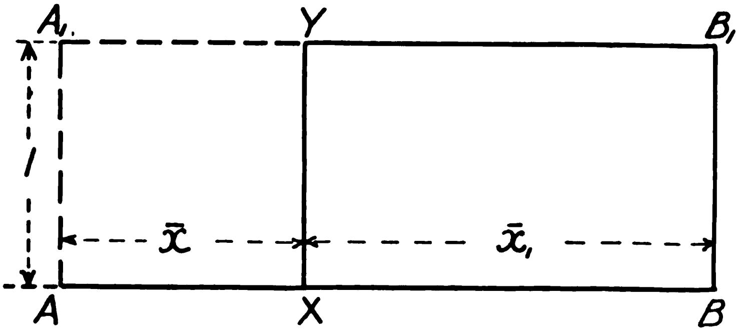


FIG. 5

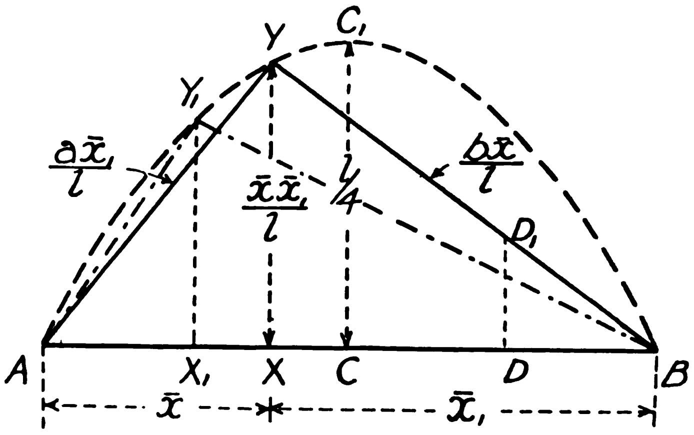


FIG 6

To draw the influence lines for a definite point X in the beam for which $x = \bar{x}$ and $x_1 = \bar{x}_1$, it is necessary to consider $\bar{x}$ and $\bar{x}_1$ as constants, and to consider a and b as variables, the load being assumed to move along the beam.

Thus, for a simply-supported beam, for any position of the load when $a > \bar{x}$ the shearing force at X will be $\frac{b}{l}$ (as $W = 1$). An ordinate representing $\frac{b}{l}$ to any convenient scale is raised at the position occupied by the load, and the extremity of the ordinate gives one point upon the influence line. The influence line for values of $a > \bar{x}$ is thus linear, and has values of 0 at B and of $\frac{\bar{x}_1}{l}$ at X.

Similarly the influence line for values of a less than $\bar{x}$ is linear, and its ordinates have values of 0 at A and of $-\frac{\bar{x}}{l}$ at X.

The complete diagram is thus $AZXYB$ (Fig. 2), and any ordinate such as CC_1 gives the shearing force at X when the unit concentrated load is at C.

It will be noticed that if the line BY be produced to cut the vertical through A at A_1, then $AA_1 = l/l = 1$. Similarly AZ produced will cut the vertical through B in B_1, where $BB_1 = 1$.

A simple method of constructing the influence line for any point, say X_1, is therefore to erect ordinates $AA_1 = 1$ and $BB_1 = 1$, join A_1B and AB_1, and erect a vertical though X_1 to cut A_1B at Y_1 and AB_1 at Z_1. The influence line is then $AZ_1X_1Y_1B$, and it is obvious that any number of such influence lines for points X, X_1, etc. can be drawn upon the one diagram.

(*b*) Beam Encastered at A and B.

In this case, when $a > \bar{x}$ the reaction $R_A = \frac{3ab^2 + b^3}{l^3}$ or $3\left(\frac{b}{l}\right)^2 - 2\left(\frac{b}{l}\right)^3$. Either expression may be used, but probably it is more convenient to plot the values of R_A directly from the base line AB, rather than to plot the two curves $3(b/l)^2$ and $2(b/l)^3$ separately, and to represent R_A by the intercepts between them.

The complete influence line is then $AZXYB$ as shown in *Fig.* 3, and it will be seen to be similar to that for a simply supported beam, but the straight lines A_1B and AB_1 of the latter are now replaced by parallel curved lines, the end values AA_1 and BB_1 each being equal to unity as before. Also when the load is in the centre of the beam, the reactions are again each equal to ½. The shearing force at X is thus the same in this case as in the case of a simply supported beam only when the load is central or when the load is just on the beam either at A or at B.

(*c*) Beam Encastered at A and Supported at B.

In this case

$$R_A = \frac{b(6ab + 3a^2 + 2b^2)}{2l^3} \text{ or } \frac{3}{2}\frac{b}{l} - \frac{1}{2}\left(\frac{b}{l}\right)^3$$

and

$$R_B = \frac{3a^2b + 2a^3}{2l^3} \text{ or } \frac{3}{2}\left(\frac{a}{l}\right)^2 - \frac{1}{2}\left(\frac{a}{l}\right)^3$$

R_A can thus be represented by the intercepts between a straight line and a cubic

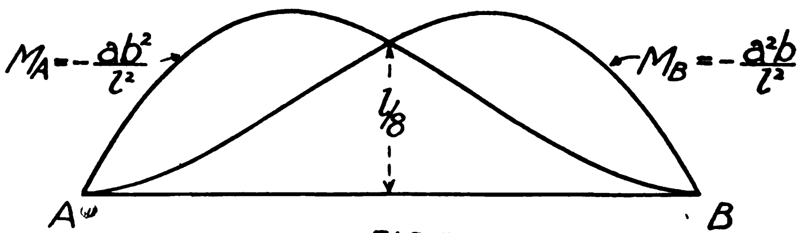


FIG. 7.

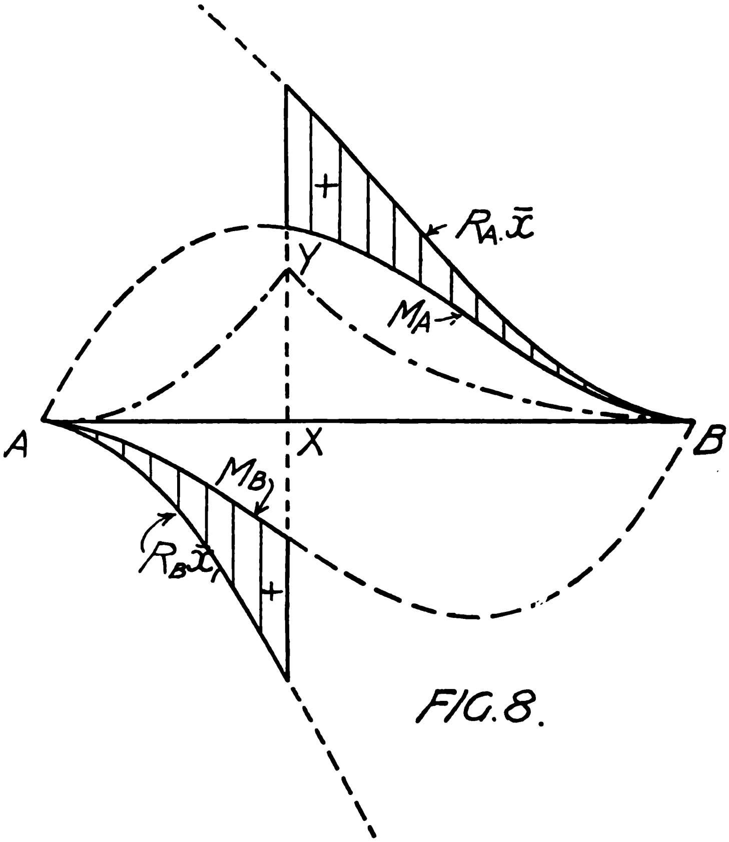


FIG. 8.

parabola, and R_B by the intercepts between a parabola and a cubic parabola, but it will be preferable to calculate the ordinates and plot them directly from a horizontal base AB.

Also as $R_A + R_B = 1$, the quickest method will be to plot the full curve BA_1 for R_A from $b = 0$ to $b = l$, and then to draw the curve AB_1 parallel to it, the intercept between the curves being 1.

The complete influence line is then $AZXYB$ (*Fig.* 4).

(*d*) Beam Encastered at A and Free at B.

For a cantilever the influence line for shearing force is shown by $AXYB_1B$ in *Fig.* 5. When the load is between B and X (i.e. $a > \bar{x}$) then the shearing force at $X = R_A$, and R_A is always equal to unity. When the load is between A and X (i.e. $a < \bar{x}$) then the shearing force at $X = 0$.

INFLUENCE LINES FOR BENDING MOMENT.

(*a*) Simply-Supported Beam.

The influence line for bending moment (M) for the point X in the simply-supported beam AB is indicated by the lines AYB in *Fig.* 6.

When $a > \bar{x}$, $M = R_A\bar{x}$ from equation (2), i.e. in this case $M = \frac{b}{l}\bar{x}$.

This expression is linear in b from B to X, the value at X being $\frac{\bar{x}\bar{x}_1}{l}$.

Similarly the influence line from A to X is linear, for $M = \frac{a}{l}\bar{x}_1$, and has an ordinate $\frac{\bar{x}\bar{x}_1}{l}$ at X.

When $AX = BX$ then the ordinate XY at $X = \frac{l}{4}$, i.e. the bending moment in the centre of a simply-supported beam carrying a central load W is $\frac{Wl}{4}$.

When therefore various positions of X are taken, the locus of Y is a parabola the ordinates being equal to $\frac{\bar{x}\bar{x}_1}{l}$ ($\bar{x}$ and $\bar{x}_1$ being of course variables). This parabola is shown by the dotted curve in *Fig.* 6. The influence line for any point X_1 can be easily drawn by erecting a perpendicular at X_1 to cut this parabola at Y_1 and joining AY_1 and BY_1, i.e. AY_1B is the influence line for the point X_1.

(*b*) Beam Encastered at A and B.

In this case the fixing moment $M_A = -\frac{ab^2}{l^2}$ or $\frac{b^3}{2} - \frac{b^2}{l}$, and this is independent of the position of X.

Similarly $M_B = -\frac{a^2b}{l^2}$, and the two influence lines are as shown *Fig.* 7.

The maximum value of M_A due to a single concentrated load W is $-\frac{4}{27}Wl$ and occurs when the load is $\frac{1}{3}l$ from A. M_B similarly has a maximum value of $-\frac{4}{27}Wl$ when the load is $\frac{1}{3}l$ from B.

When the load is central $M_A = M_B = \dfrac{Wl}{8}$.

The bending moment at X is given by equations (2) or (2a).

$$\begin{aligned} \text{i.e., } M &= R_A\bar{x} + M_A \text{ when } a > \bar{x} \\ \text{and } M &= R_B\bar{x}_1 + M_B \quad ,, \quad a < \bar{x}. \end{aligned}$$

For any particular position of X, $\bar{x}$ and $\bar{x}_1$ are constants so that the influence line diagram for M is given by the intercepts between the two influence lines for $R_A\bar{x}$ and M_A, and between those for $R_B\bar{x}_1$ and M_B, as shown in *Fig.* 8.

For any other position of X, the M_A and M_B curves will be unaltered: those for $R_A\bar{x}$ and $R_B\bar{x}_1$ will remain of the same general shape, but will be altered in height owing to the new values of $\bar{x}$ and $\bar{x}_1$.

If preferred the intercepts between the component curves may be calculated, and plotted directly upon a straight base line as in line AYB (*Fig.* 8). This influence line in *Fig.* 8 is drawn for a position X where $\bar{x} = \cdot375l$, and the bending moment is positive for all values of a.

For the bending moment at any point X to be negative, when $a > \bar{x}$, M_A must be greater than $R_A\bar{x}$,

$$\text{i.e. } \frac{ab^2}{l^2} > \frac{3ab^2 + b^3}{l^3}\bar{x}$$

$$\text{or } a > \frac{l\bar{x}}{l - 2\bar{x}}.$$

But a $> \bar{x}$ and $< l$, so that substituting these limiting values for a, it is seen that $\bar{x}$ must lie within the range from $\bar{x} = o$ to $\bar{x} = \dfrac{l}{3}$.

Similarly, when $a < \bar{x}$ the bending moment will be negative, only if $\bar{x} > \frac{2}{3}l$, and when $b > \dfrac{l\bar{x}_1}{l - 2x_1}$.

Thus, if $\bar{x} < l/3$ or $> 2l/3$, the bending moment is negative at X for certain positions of the load, i.e. when $a > \dfrac{l\bar{x}}{l - 2\bar{x}}$ or $b > \dfrac{l\bar{x}_1}{l - 2\bar{x}_1}$.

It follows from the general properties of influence lines therefore, that whatever form of direct loading be applied to a "fixed" beam, the centre third of the span can only be subjected to positive bending moments, and hence it is obvious that the two points of contraflexure must both be situated outside this centre third of the span.

(*To be continued.*)

REINFORCED CONCRETE SWIMMING BATH AT PARIS.

By P. CALFAS, Ing. E.C.P.

A REINFORCED concrete swimming bath recently built by the Municipality of Paris at " La Butte aux Cailles," has several features of interest from the constructional and planning points of view. The site derives its name from a well from which water is obtained at a temperature of 83 deg. Fahr., and the cost of warming the water for the bath is thus considerably reduced. A total of 400,000 gallons of tepid water is obtained from the well every twenty-four hours, which is sufficient to renew the water in the bath two or three times a day if desired. The depth of the well is 1900 ft.; it is lined with tubes 4 ft. in diameter at the top decreasing to 1 ft. 4 in. at the bottom.

When, in 1920, the Municipality decided to erect the baths a building containing 50 shower baths already existed on the site, and this structure was enlarged to provide 100 shower baths and retained as part of the new establishment.

The present building covers an area 213 ft. in length by 131 ft. wide, with the swimming pool in the middle and the dressing rooms and shower baths in two-story buildings along the sides.

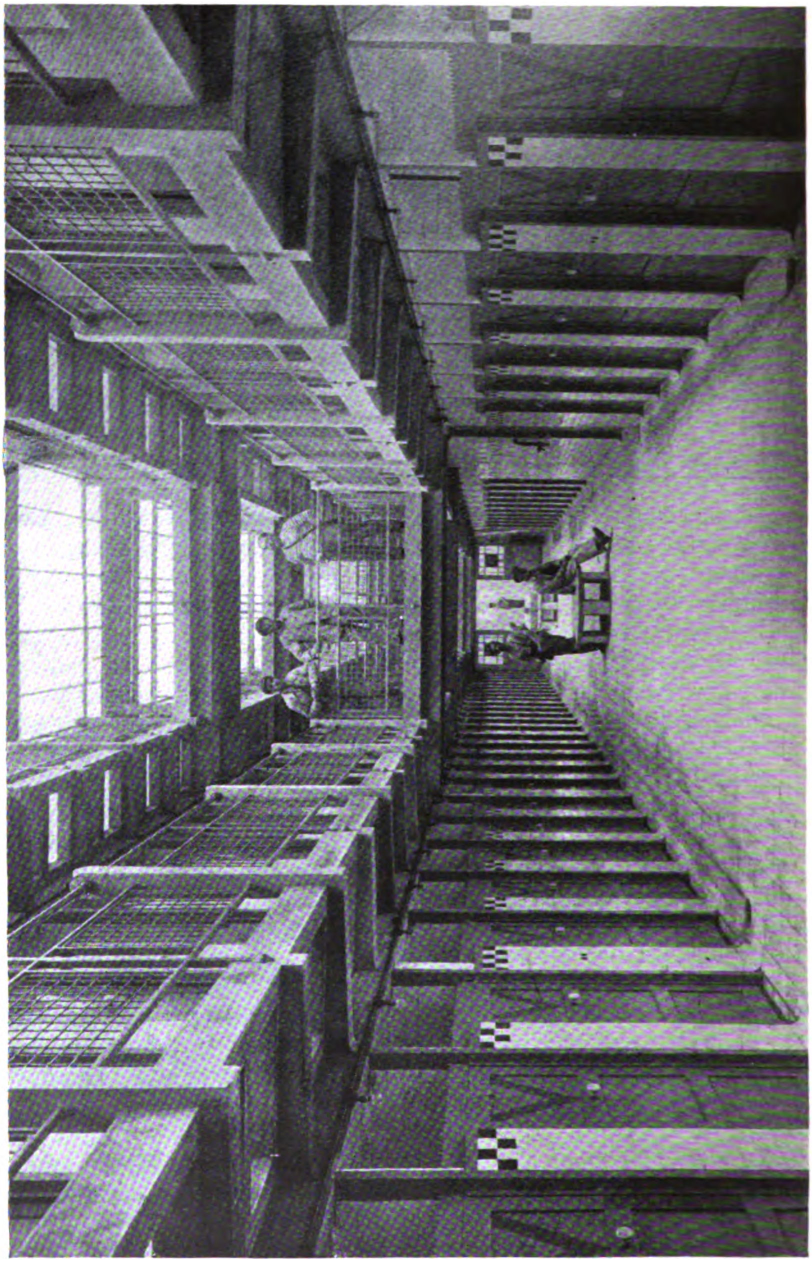
The hall containing the swimming pool is built entirely of reinforced concrete, the roof being supported on a double system of arches superimposed one above the other. The main arches have a span of 54 ft. 6 in., the height from the floor level to the crown is 51 ft. 6 in., and the spacing from centre to centre is 17 ft. 9 in. The smaller arches above spring from the lower arches and support the centre portion of the roof. The sloping lower portion of the roof is built in two leaves so as to provide an escape for the warm humid air, which passes upwards between the double walls and out of the building through ventilators at the sides of the middle portion of the roof and around the skylights. Lighting is provided by the skylights and windows. A passageway around the roof is provided, constructed of reinforced concrete. The spaces in the roof between the arches are filled in with concrete slabs, faced on the outside with layer of cement-sand concrete three-quarters of an inch thick spread on a mesh reinforcement.

The pool is 109 ft. 4 in. long by 39 ft. 4 in. wide, the depth of water varying from 2 ft. 6 in. at the shallow end to 9 ft. at the deep end. In order to prevent damage to the pool owing to any settling of the arches or walls which might take place, the bottom of the basin is supported on four rows of piers spaced at 8 ft. 10 in. centres carried down to an independent reinforced concrete raft. The concrete for the walls and bottom of the pool was mixed in the proportion of 730 lbs. of cement to 20 cu. ft. of sand, which has been found to give a thoroughly watertight tank without rendering.

A novel feature in this bath is the installation of four rows of electric lights in glass-covered cavities along the bottom of the bath which form " tracks " which may be followed by swimmers when using a stroke which keeps the face under water for considerable distances.

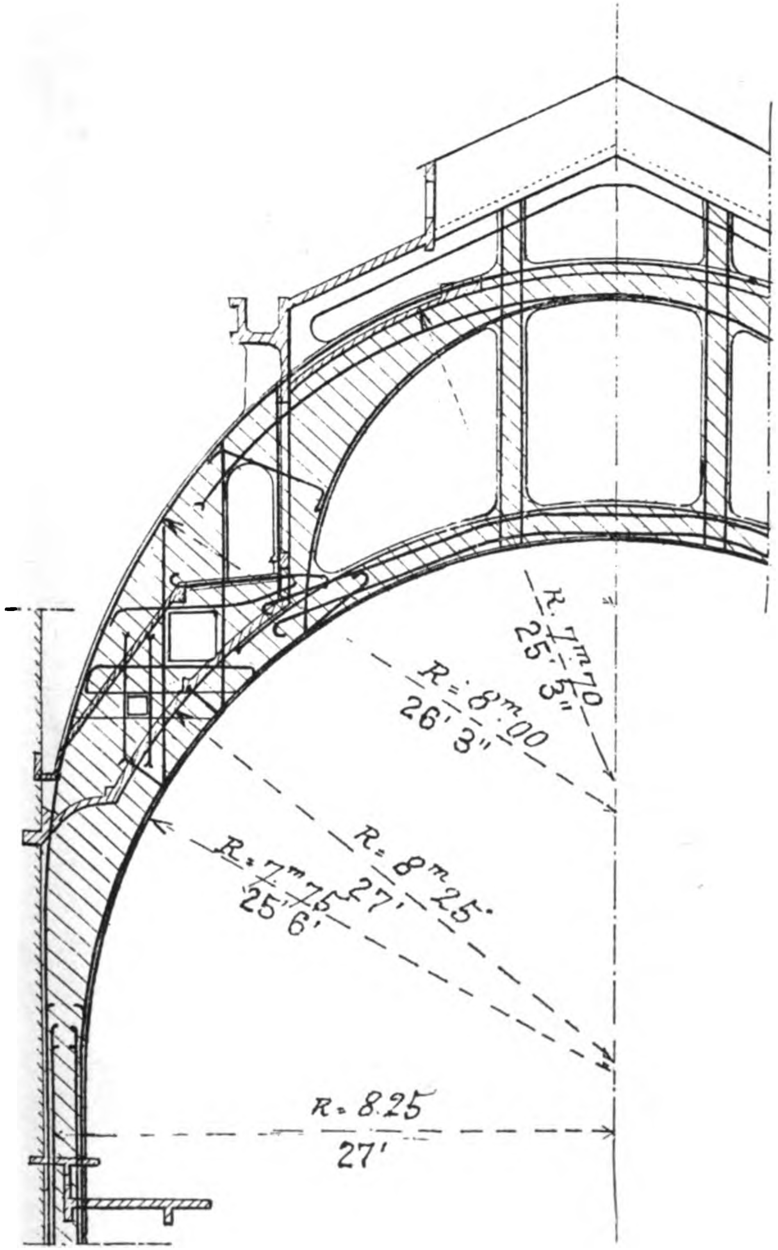
To a height of 6 ft. 6 in. the walls are faced with blue and white ceramic tiles. At one end is a balcony with accommodation for 400 spectators, while a smaller gallery at the other end accommodates the judges when racing events take place.

The usual practice in this country of providing dressing boxes around the

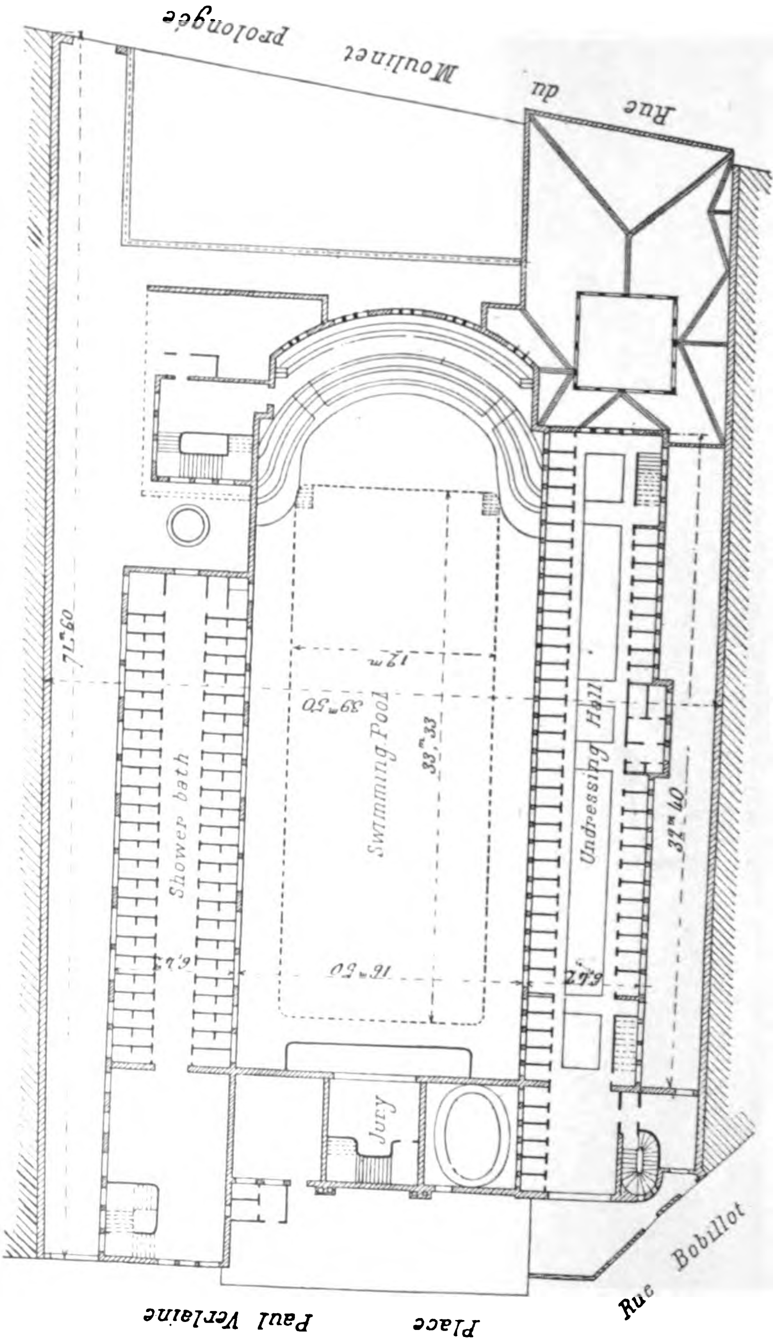


REINFORCED CONCRETE SWIMMING BATH IN PARIS.

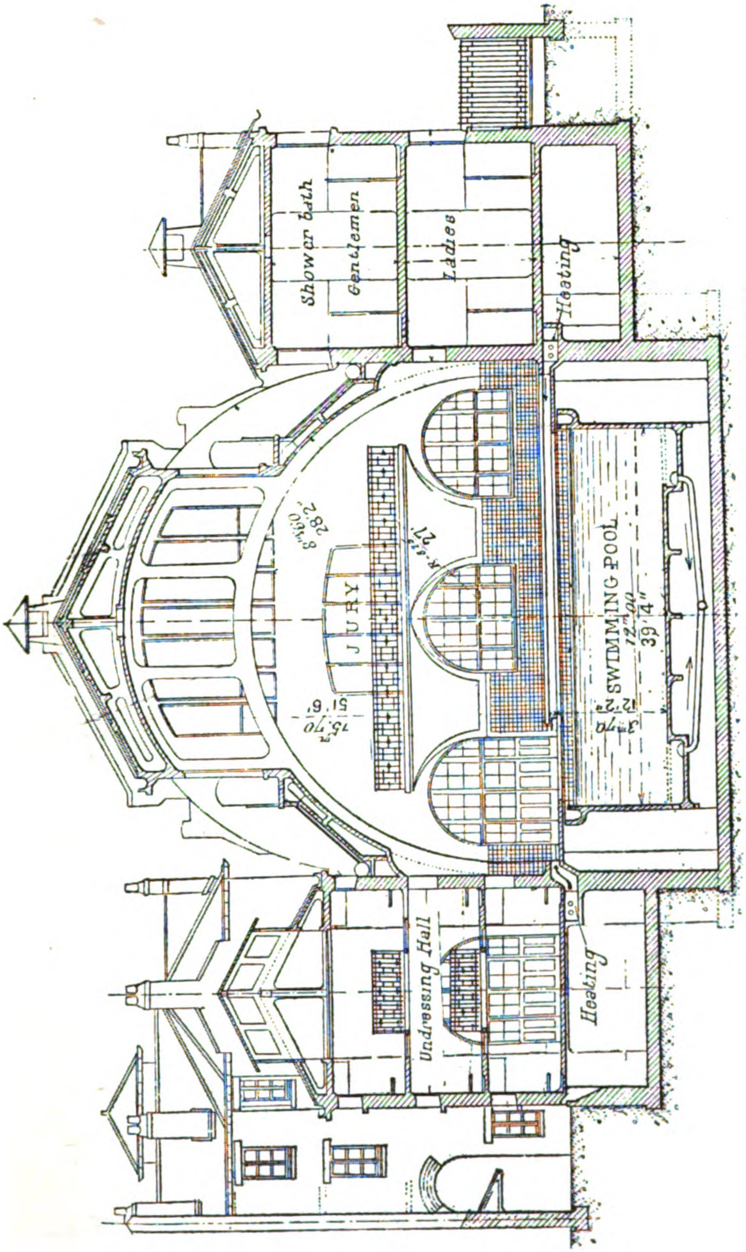
side of the pool has been departed from, and the dressing accommodation is situated in a separate hall at the side. The dressing-boxes are together at one end of the hall, and bathers must pass through the part containing shower and foot baths before entering the swimming bath. The boxes are entirely built of



SECTION OF REINFORCED CONCRETE ARCH.



REINFORCED CONCRETE SWIMMING BATH IN PARIS: PLAN.

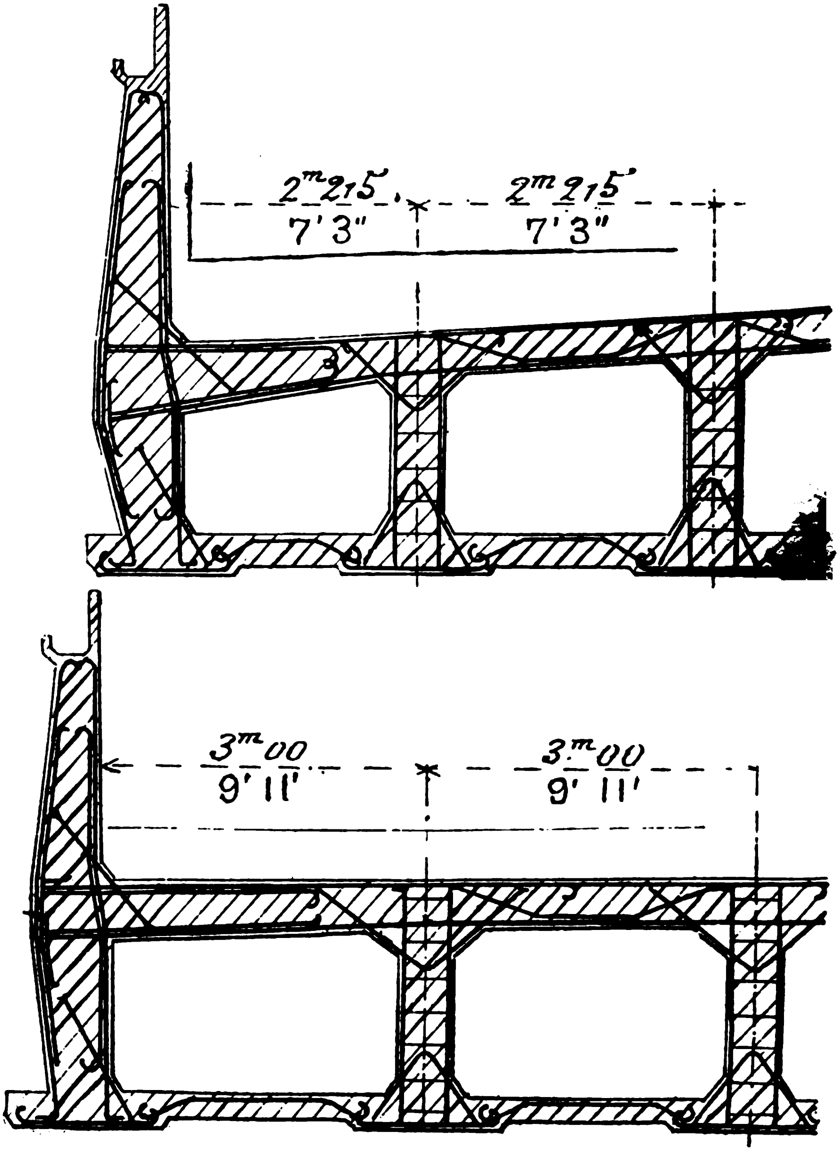


REINFORCED CONCRETE SWIMMING BATH IN PARIS: CROSS-SECTION.

concrete, with concrete seats and concrete clothes pegs, and there is a concrete foot-bath, supplied with hot water, in the corner of each box. Altogether there are 166 boxes, each measuring 3 ft. 3 in. square, arranged on three tiers.

The heating chamber is in the basement below the dressing hall, and a reinforced concrete chimney 131 ft. high has been built.

The architect of the building is M. Louis Bonnier, and the builders were the Baffrey-Hennebique Company.



LONGITUDINAL AND TRANSVERSE SECTIONS AT ONE END OF POOL.

CONCRETE ACCESSORIES FOR A POWER HOUSE AT SAMBHAR, RAJPUTANA.

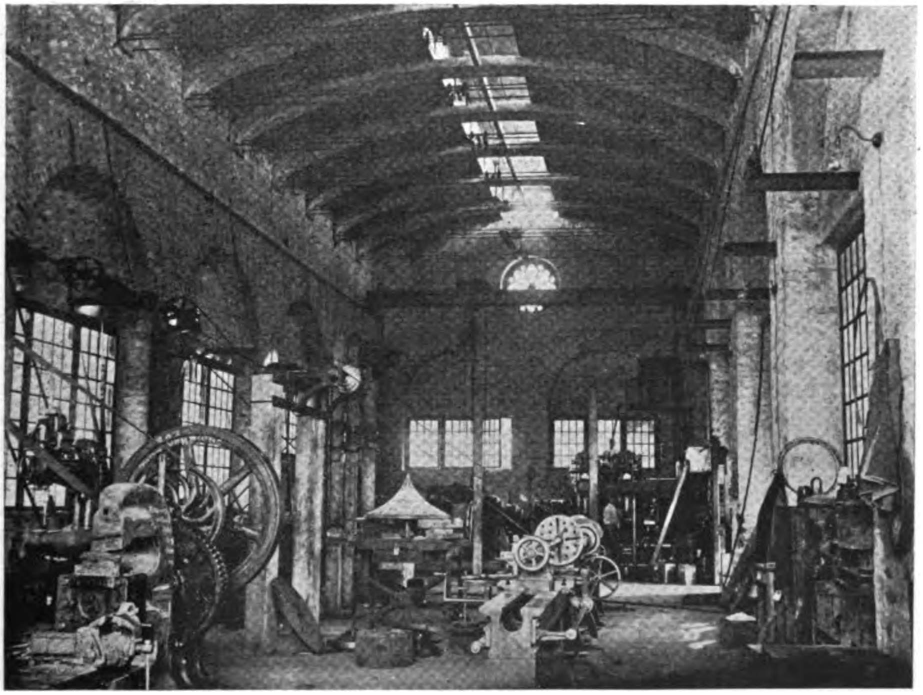
By S. A. BUNTING, M.A., M.Inst.C.E.

THIS power house, 102 ft. by 32 ft. inside, is built of marble waste. The roof is carried on the end walls and eleven intermediate concrete arches 2 ft. wide by 10 in. thick, each reinforced top and bottom with three ¾-in. squares. The thrust of each arch is taken by two 12 in. by 4 in. mild steel channels each 2 ft. long tied by three 1-in. tie rods. The reinforcing rods continue past these channels to reinforce the cantilever continuations of the arches which hold the eaves.

The centering was built up on a 5-ton travelling crane, and used eleven times, the only extra carpenter's work required each time being the removal and replacement of the side forms of the arch and the struts on one side to allow traversing past the tie rods. Twenty-four hours after casting the three tie-rods were tightened slowly and evenly. This pinched the arch ⅛-in. or so clear of the centering and allowed of its removal. The cantilever portions were cast after this pinching had been effected.

Rajputana stone slab roofing, weighing with its concrete rendering some 70 lb. per sq. ft., was used for the cantilevered portion and over the walls, and a double slate roof with 4 in. air space, weighing 32 lb. per sq. ft., covers the rest of the building. This loading somewhat reduced the thrust on abutments and tension in the tie rods.

The double slate roof was made of slate slabs 2 ft. square and ½-in. and ¾-in. thick. Old 10-lb. flat-foot rails were laid across the arches and the lower slates set in cement mortar to rest on the lower flanges of these rails. Forms 4 in. high were then set up on these slates at each side of the rails, held together by wooden cramps. These, filled with concrete, formed reinforced concrete girders, the heads of the rails constituting the tension members proper. Nails were left projecting from the centre of each girder ; the upper layer



POWER HOUSE AT RAJPUTANA.

of slates was then laid on these girders, the nails bent over to hold them, and the whole cement-rendered smooth and level. The clerestory portion was built in a similar manner and a cheap and light roof which is sunproof resulted.

The foundations of the engines and alternators were cast as monolithic reinforced concrete girders. In the usual procedure the foundation is built first and holes left for the foundation bolts to be grouted in afterwards, but with this practice there is danger that owing to shrinkage of the grout on setting, and subsequent tightening of the bolts followed by bed-plate vibration, the adhesion between the grout round the bolt and the surrounding concrete will be destroyed. The bolt and its grout-sheath are free to vibrate slightly without imparting vibrations to the surrounding concrete. So long as the surrounding concrete is not cracked the engine may be safely held down by such means, but the money spent on the heavy foundation is largely wasted ; the main purpose of it, the amortisation of engine vibration, is not served.

In this case, the foundation pit being dug, the engine bedplate and alternator stator and bearing pedestals were set up in true alignment on rails over the pit. The foundation bolts were of U form, going down from one side of the bedplate towards the bottom corner of the pit, across the bottom, and up to the corresponding lug on the bedplate the other side. Throughout the length of the foundation, at the bottom corners, two rails were suspended in these U bolts and two more parallel to them above, also wired firmly to the U bolts as near the top of the foundation block as the flywheel and stator recesses permitted. The whole was concreted up to the bedplates and 1 in. above.

The foundation dimensions demanded by the engine makers were adhered to, but there is little doubt that with a monolithic reinforced concrete girder they could be safely reduced. The extra expense in any case is slight beside the extra life given to the whole plant by the amortisation of vibration.

The cooling tower consists of a masonry hot well 24 ft. diameter by 6 ft. deep, half in and half out of the ground. Some 3 ft. above water-level reinforced concrete radial girders supported on a central pillar and the circumferential wall carry a stone floor for a room utilised as an office.

At 18 ft. above ground level is the bottom of a 10,000-gal. reinforced concrete tank, 24 ft. diameter by 6 ft. deep, with an inspection gallery 2 ft. wide around it. The floor of this tank, spanning the whole 24 ft., is of T-beam construction, there being three ribs. The tank has never leaked. The whole is roofed by a wood slat roof carried on reinforced concrete columns extended from the tank walls.

An underground oil tank to hold 80 tons of crude oil, 25 ft. diameter by 6 ft. depth, consists of a plain lime concrete floor, a lime masonry dividing wall, and two concentric thin masonry circumferential walls between which cement concrete 6 in. thick was poured, reinforced every 9 in. with circumferential hoops. The whole, both floor and walls, was carefully cement plastered on the inside. A 4 in. connection to each side of the tank at the lowest point of the floor permitted the introduction of water. By keeping the oil floating on water, dirt in the oil can sink, and moreover any leaks in the floor will lose water and not oil. A few patches on the outside revealed the passage of oil, estimated at 10 gallons in 24 hours when under full head, though the tank had been absolutely tight when tested with water. The cement plaster was chipped off and done again ; considerable improvement was registered but one or two small patches still appeared. A mixture of plaster of Paris, resin, and caustic soda was tried ; this may be efficacious for oil, but if any water gets at it the caustic soda dissolves, and the result is most undesirable in a fuel-oil tank. Finally, to make absolutely sure of it, a masonry wall was built right round the tank leaving a foot space ; this space is kept filled with water so that the pressure on any pores is from the outside.

Triangular pre-cast reinforced concrete columns carry the countershafts for lathes, etc. ; here again the effect of weight in reducing vibration is valuable.

RAPID CONCRETE BUILDING.

A RECENT issue of "Engineering News-Record" gives the following account of an instance of the remarkably rapid construction in reinforced concrete of two adjacent sixteen-story buildings in Chicago. All foundation and framework construction was carried out within thirteen weeks. These buildings (*Fig.* 1) are 111 ft. by 52 ft., with the width reduced to 40 ft. in the rear portion, and with a height of 173 ft. from sidewalk to roof. They are separated by a terraced garden court 46 ft. wide. In structural design they are notable for the use of the "Emperger" system of solid cast-iron cores and spiral wrapping in the columns and for the use of beam and girder floors.

Since the site is over a bed of gravel some 25 ft. deep no piling was needed and the foundations consist of spread footings for the interior columns and a continuous wall for the outer columns. This wall, 2½ ft. thick and 8 ft. high, with a 13½-ft. footing, is designed to act as a distributing girder and was cheaper than separate footings. The wider front portion of the building, where it abuts on the building line, has six columns seated on a 24-in. slab 46 ft. by 23 ft., resting on the gravel. These foundations were designed for a load of 4,000 lb. per sq. ft. A rich concrete, 1 : 1 : 2 mix, was used for the upper part of all isolated footings.

All the columns are 23 in. square from top to bottom, and consequently all girders, beams, and lintels are uniform from story to story. This arrangement reduced the number and variety of forms and expedited their erection. The framing plan is shown in *Fig.* 2. The solid cast-iron cores for the columns reduce gradually from 8-in. diameter at the base to 2½-in. at the seventh floor, above which the standard spirally-hooped concrete columns continue to the roof. The cores of interior columns are embedded in the footings (*Fig.* 3), where they are surrounded by spiral reinforcement, but the cores of the exterior columns rest on plates on the foundation wall, which is reinforced beneath them to provide for the diverging distribution of the load.

Floor panels are mainly 20 ft. by 20 ft. and 17 ft. by 17 ft. centre to centre of columns and are subdivided by beams of 6-ft. spacing. The large area of slab resulting from this arrangement, as compared with a ribbed slab floor, is considered to simplify greatly the arrangement and erection of pipes and conduits for heating, plumbing, and electric service. The depth of beams is 12 in., including the 3-in. slab. Since deep girders crossing the rooms would have been unsightly, the girders in many cases were kept at the same depth as the beams, the required strength being obtained by increased width and heavy reinforcement.

Because the buildings are high and narrow, ample reinforcement as wind bracing was provided at connections of wall columns and lintel girders and also at two intermediate planes between three columns. Reinforcing rods are of high-

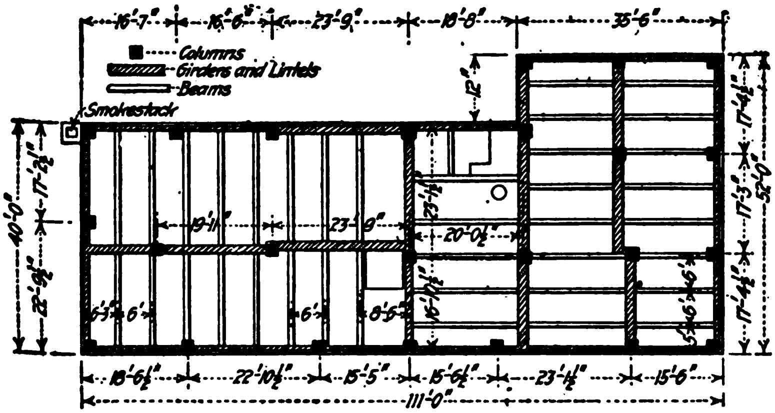


FIG. 2.—FRAMING PLAN.

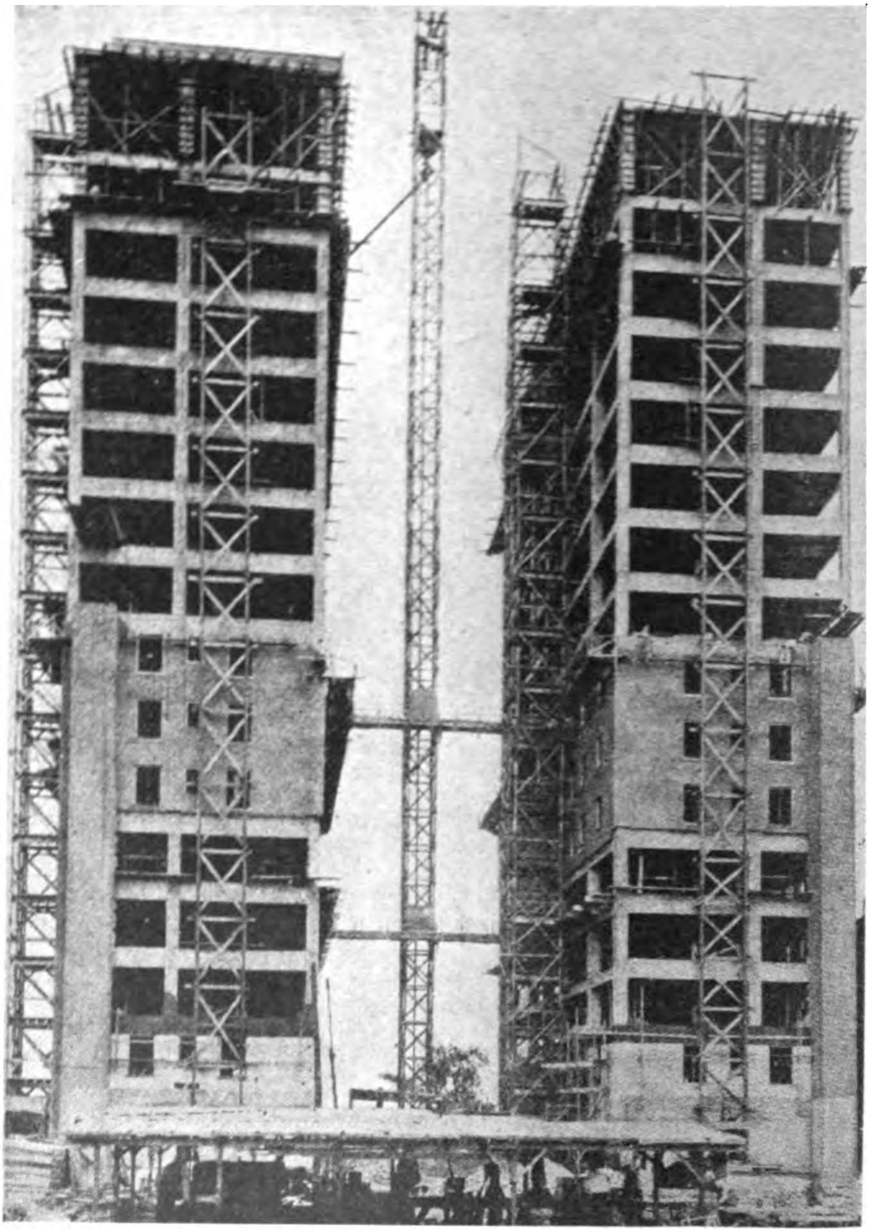


FIG. 1.—RAPID CONCRETE BUILDING.

carbon steel, with hook ends. They are bent to shape at the mill, the steel being too hard for bending on the work. The floors are designed for a 40-lb. live-load.

Stone and brown brick are used for covering the exterior walls. Artificial stone was used for the decorative work and trim of the roof and upper floors. The cornice, 3½ ft. high, with 14-in. projection, was cast monolithically. The roof is similar to the floors and is covered with tar-and-gravel composition roofing.

Complete design of forms in the engineer's office expedited the work materially. Every variety of form was drawn in detail and marked for erection, with bill of material for each form. Thus nothing was left to the carpenter foreman except to see that the work was done according to the drawings, while the erection foreman knew exactly what forms to use for every part of the concreting. It was found that each form could be used about six times, after which it would require so much repair that it was cheaper to use a new form, the old material being utilised for various purposes, particularly for shed construction and wall forms on other work.

A single concreting plant having a

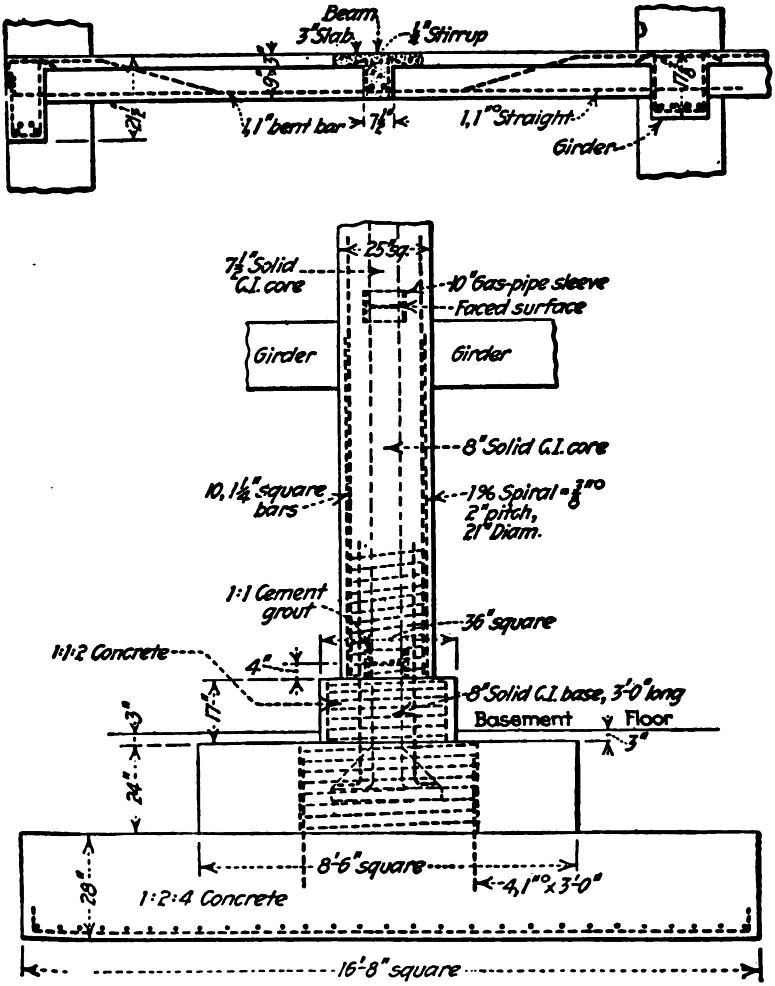


FIG. 3.—COLUMN AND FLOOR DESIGN.

mixer of 21 cu. ft. capacity and a bucket elevator tower with 50-h.p. electric hoist was placed in the court between the two buildings. This plant delivered concrete to each building on alternate days. Concrete was chuted from the tower to a hopper on the floor for charging wheeled carts which delivered it to the forms. Each building was served by three material elevators, making six in all. In view of the rapid progress required, all these elevators were built and extended as the building rose. One of the three elevators, placed at the north long side, was of the platform type with a platform large enough for three wheelbarrows. At each end of the building was a slide elevator for such long materials as lumber and reinforcing bars. Ginpole derricks were also used in hoisting and placing the forms. Four hoisting engines were used, two for each building. One at the front operated the platform elevator, slide elevator and derrick; one at the rear operated the second slide elevator and ginpoles. Bridges spanning the court were built at different floors to facilitate passage between the two buildings (*Fig.* 1).

Breaking tests of specimen beams were an important feature of the work. For each run of concreting four beams 4 in. by 6 in. and 8 ft. long were tested at intervals of about three days The testing apparatus consisted of a lever with arms 13 in. and 9 ft. 9 in. long, pivoted in a frame and loaded at one end. A roller formed the contact point on the test beam. By these tests made on the work it was easy to determine definitely how soon the falsework might be removed from under the forms, thus effecting considerable saving in the amount of falsework timber. For complete assurance of strength, the bottom reinforcing rods of the test beams were placed on the bottom of the form so that the full beam depth was known and there was no question as to the distance of the rods from the bottom of the beam.

Progress on the concrete work averaged two stories per week in each building, and in several cases the forming and pouring of an entire story was done in two days. On June 1 the foundations were completed and some column forms set. On June 8 one building had three stories and the other two stories poured. On July 13 both buildings were ten stories high and on August 1 this had increased to fifteen and fourteen stories respectively. The roof of one was completed on August 16 and that of the other on August 18. These times are for the concrete frame only, the wall construction being carried on simultaneously. For the concreting the number of men employed was forty, working one shift of eight hours.

The structural design was prepared by Mr. L. J. Mensch, consulting engineer, Chicago, who also was the general contractor for the entire work. The architect was Mr. W. W. Alschlager, Chicago.

NEW CONCRETE BRIDGE OVER THE THAMES.

WORK is now commencing on the demolition of the Albert Bridge over the Thames near Datchet, which is to be replaced with a reinforced concrete structure, making the third bridge of this material to be built over the Thames. It will be in the Renaissance style, but with squared rubble towers, to obviate conflict with the Norman architectural surroundings. The design is by the County Surveyors of Berkshire and Buckinghamshire, Lieutenant-Colonel J. F. Hawkins and Mr. E. Winfield, respectively.

The bridge will consist of two unequal span arches, that on the Berks side 75 ft. and that on the Bucks side 110 ft., with a centre cut-water pier 15 ft. wide, and is designed to carry all classes of modern traffic. The bridge will be built on the system of the Trussed Concrete Steel Company, Limited, of 22 Cranley Gardens, S.W.7, by Messrs. A. Jackaman and Son, of Slough, Bucks.

Proposed Chair of Cement Engineering.

ACCORDING to the *Yorkshire Post* a proposal is on foot for the establishment of a Professorship of Cement Engineering at Leeds.

THE MODULUS OF ELASTICITY OF "SPUN" CONCRETE IN TENSION.

The following report of an investigation on spun concrete pipes has been received from the Building Research Board of the Department of Scientific and Industrial Research.

INTRODUCTION.

In the design of all ordinary reinforced concrete structures it is the usual practice, principally on account of the comparatively low tensile strength of concrete, to ignore entirely the part it plays in taking up tensional stresses. As a result there is a dearth of information regarding the modulus of elasticity of concrete in tension. What work has been done in this direction seems to indicate that for all practical purposes the compression and tension moduli are equal for concrete placed in the ordinary manner.* A special case arises in dealing with concrete pipes compacted by other than ordinary means and used under conditions in which the stresses are wholly tensile, due to internal pressure. Into this category sometimes come "spun" concrete pipes formed in spinning cylindrical moulds in which the concrete is compacted solely by centrifugal force.

As the subject is one of fairly wide interest, the investigation described in this report was undertaken by the Building Research Board of the Department of Scientific and Industrial Research at the request of The Stanton Ironworks Co. Ltd., by whom the pipes tested were manufactured. The work was carried out at the Building Research Station by Messrs. W. H. Glanville, B.Sc., and H. E. Comben, B.Sc., A.M.Inst.C.E.

DESCRIPTION OF PIPES.

The pipes are generally known as "Hume-Stanton" pipes. The process of manufacture appears to have the effect of producing an extremely dense concrete with an internal surface of practically neat cement. During manufacture the optimum speed of spinning is obtained by experiment and the period of spinning required is judged by the operator.

All the pipes tested were 6 ft. long, 4 in. internal diameter and 6 in. external diameter.

The following particulars as to the proportioning and curing were supplied by the Stanton Works :—

Pipe No.	Proportions by Weight		Water (% by weight of mixture)
	Cement	Leighton Buzzard Sand	
	Per Cent.	Per Cent.	
1	34	66	11·5
2	34	66	11·5
3	34	66	11·5
	Cement	Local Sand and Crushed Granite	
4	24	76	12·0
5	27½	72½	12·5
6	27	73	12·5
7	27	73	12·5

The pipes were steamed for 7 hours at 120° F., when the steamer was allowed to cool. After a further period of 10 hours the pipes were withdrawn and immersed in water for 21 days. They were then despatched to the Building Research Station where they were stored in a dry shed until tested at the age of about 3 months.

SCHEME OF TESTS.

The tests were divided into three groups, as follows :—

(1) Transverse tests.
(2) Compression tests.
(3) Tension tests.

In the first instance the transverse tests and compression tests only were carried out, and it was thought that if the values of the moduli of elasticity from these two series were approximately equal, sufficient evidence would have been obtained that the modulus of elasticity in tension was equal to that in compression. These results, however, did not show sufficient agreement, and the third series was proceeded with.

DESCRIPTION OF TESTS.

(1) TRANSVERSE TESTS.

The pipes, as beams, were bedded with plaster in hard-wood blocks, 5 ft. 6 in.

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* Professor W. K. Hatt: *Journal* of the Association of Engineering Societies, 1904, p. 323.

between centres, resting on half roller abutments, the whole being supported on a rigid frame. A similar hard-wood block was fixed with plaster to the top centre of the beam and the load was applied through a horizontal length of iron tube free to move in a groove on top of the block and with its axis at right-angles to the pipe. A bin suspended from this iron tube enabled loading to be effected by pouring in weighed quantities of water up to a predetermined safe load; to unload, the water was run out in approximately equal quantities, which were weighed.

Deflection was measured by observing the distance between two fine needle points through a travelling microscope fitted with an eyepiece scale. This scale was calibrated for each set of readings by means of a micrometer head attached to the microscope. The whole of a set of readings could be taken with one setting of the microscope so that it was not touched during an experiment.

The "moving" needle was fixed to a stirrup passing under the pipe and fastened to the pipe by two pointed screws diametrically opposed on the centre line of the pipe. The "zero" needle was carried on a frame composed of longitudinal angle bars and saddles, each saddle being attached by two pointed screws to the centre line over the abutments.

The observed movement of the "moving" needle gave the gross deflection; the movement of the "zero" needle gave a correction for the settlement of the supports on the framework.

By using needles in this way it was possible to get both to lie in a plane so that the two were in focus at the same time. It was found to be impossible to do this with cross-wires.

Increments of 20 lbs. of water up to 250 lbs. were poured into the bin and the needle point readings taken each time. Three sets of loading and unloading readings were taken, as concrete exhibits a permanent set during the first one or two loadings. A typical set of curves obtained is shown in *Fig.* 1. Calculations for the modulus were made from the standard formula for the deflection of a beam. The values obtained are given in Table I.

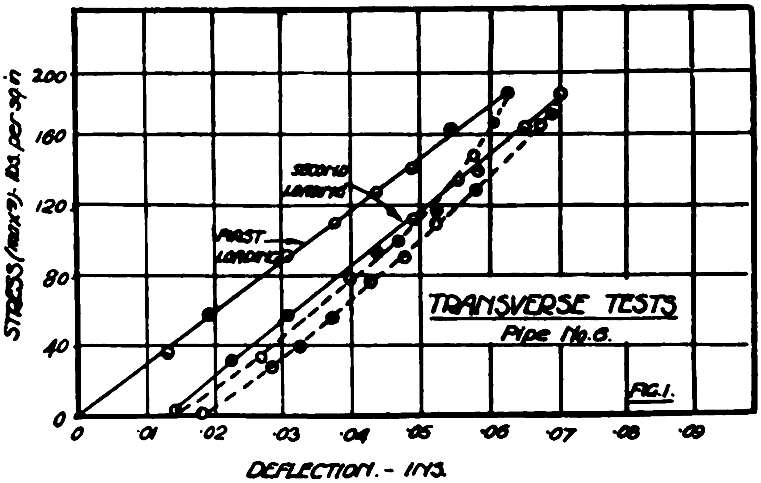


Fig. 1.

(2) COMPRESSION TESTS.

The pipes were cut into appropriate lengths by means of a concrete saw (*Concrete, Plain and Reinforced*, Taylor and Thompson, 3rd Edition, page 342), and the modulus of elasticity in compression determined in a normal manner.

The test pieces, bedded top and bottom on thick card and with a swivel-block at the top, were placed in a Buckton single-lever testing machine. Loading was carried up to about 1500 lbs. per sq. in.

Deflection was measured by means of a Lambs' roller mirror extensometer. In this instrument the strain on a length of

TABLE I

Results of Transverse Tests

Pipe No.	Tangent E at 200 lb./sq. in.								
	1st		2nd		3rd		Mean		Mean.
	Ldg.	Unldg.	Ldg.	Unldg.	Ldg.	Unldg.	Ldg.	Unldg.	
1/1*	3·95	3·95	5·13	5·64	5·64	4·95	5·75	6·21	5·98
1/2	5·03	7·09	6·16	6·63	5·92	6·70			
1/3	5·88	6·85	6·35	7·04	7·69	7·01			
2/1	5·56	8·20	5·69	7·03	5·63	7·21	5·63	7·44	6·50
3/1	6·28	6·85	6·30	6·25	5·76	6·85	6·11	6·65	6·38
4/1	4·75	4·94	5·00	5·06	4·91	5·13	4·89	5·05	4·97
5/1	4·19	5·02	4·43	5·15	4·62	4·82	4·50	4·95	4·72
5/2	4·17	4·40	4·73	4·90	4·78	5·05			
6/1	3·87	4·80	4·35	4·67	3·76	4·65	3·99	4·71	4·35
7/1	5·35	5·39	4·43	5·28	5·16	5·16	4·98	5·26	5·12

(*All values to be multiplied by* 10^6 *lb./sq. in.*)

* In each case the first number represents the mix, and the second number the particular pipe of that mixture.

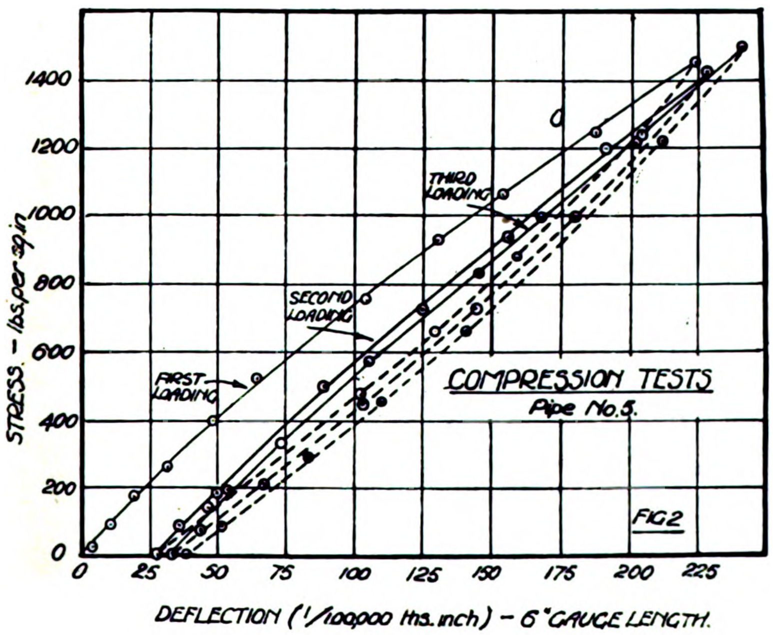


Fig. 2.

the test-piece produces rotation of two mirrors fixed on opposite sides of the specimen, and deflecting the line of sight from a telescope to a fixed scale ; the limit of magnification of the scale reading is determined by the distance at which the scale can be placed and yet easily read through the telescope. A test length deflection of 1 by 10^{-5} ins. can be observed with ease.

TABLE II

RESULTS OF COMPRESSION TESTS.

Pipe Section No.	Breaking Load lbs./sq. in.	Mean Breaking Load lbs./sq. in.	Tangent *E* at 200 lbs./sq. in.			Tangent *E* at 700 lbs./sq. in.		
			Mean		Mean	Mean		Mean
			Ldg.	Unldg.	*E*	Ldg.	Unldg.	*E*
1/1/A	5680	5730	8·80	8·28	8·54	8·24	7·87	7·97
1/1/B	5970					7·60	7·45	
1/2/A	6730					6·60	6·45	
1/2/B	5060					7·10	7·13	
1/3/A	5690					9·80	9·98	
1/3/B	5230					9·00	8·53	
2/1/A	8650	7515	6·95	6·49	6·69	7·18	7·18	6·60
2/1/B	7050					6·77	7·08	
2/2/A	6780					5·90	5·95	
2/2/B	7580					6·30	6·43	
3/1/A	5920	6180	6·69	6·29	6·49	6·63	6·65	6·53
3/1/B	6440					6·38	6·44	
4/1/A	4020	3605	5·46	4·14	4·80	4·45	4·48	4·78
4/1/B	3190					5·11	5·06	
5/1/A	3440	3690	4·81	3·86	4·31	3·05	4·17	4·14
5/1/B	3740					4·10	4·32	
6/1/A	4410	4410	5·73	4·82	5·27	4·40	4·62	5·24
6/1/B	—					5·94	5·94	
7/1/A	3830	3200	3·48	2·73	3·11	3·40	3·56	3·40
7/1/B	2570					3·23	3·41	

(*All values of E to be multiplied by* 10^6 *lbs./sq. in.*)

The results are shown in Table II, while *Fig.* 2 illustrates a typical case.

(3) TENSION TESTS.

These tests were made on a 3-ft. length of pipe in order to avoid local stresses near the clamps affecting the extensometer readings. Extensions were measured by means of a Lambs' extensometer as used in the compression tests.

The load was applied through special clamps, made to fit the ends of the pipe closely, and fastened to the cross-heads of a 10-ton Buckton single-lever testing machine. It was desired to get readings of load-extension right up to the breaking point in tension, but it was found that the pipes broke in every case just against the clamps. To obviate this slots were cut in the pipe to reduce the area and bring the fracture near the extensometer. Although this was successful in so far as stress at the centre was increased, actual fracture was not obtained.

The results are given in Table III. The observations made on Pipe No. 6 are plotted on *Fig.* 3.

TABLE III

RESULTS OF TENSION TESTS

Pipe No.	Tangent E at 800 lbs./sq. in.						Mean E.	Values of E at breaking of pipe at clip
	1st		2nd		3rd			
	Ldg.	Unldg.	Ldg.	Unldg.	Ldg.	Unldg.		
1/1	5·76	6·27	5·37	6·22	5·60	6·16	5·88	At 370 lbs./in.^{2} Tang. E = 5·03 Chord from origin = 5·57
1/2	6·26	6·26	5·61	6·16				
1/3	5·04	6·00	5·56	5·84				
2/1	5·41	6·23	5·90	5·90	5·66	6·07	5·87	
2/2			Not	Tested				
3/1	6·47	6·47	6·59	6·59	6·53	6·53	6·53	
4/1	3·84	4·27	4·10	4·22	3·97	4·25	4·11	
5/1	4·32	4·71	4·14	4·67	3·77	4·17	3·97	At 250 lbs./in.^{2}, Tang. E = 2·29, Chord — 3·29
5/2	3·16	3·72	3·44	3·64				
6/1	4·00	4·47	4·18	4·51	4·09	4·49	4·29	
7/1	4·10	3·61	3·64	3·80	3·47	3·86	3·67	At 270 lbs./in.^{2}, Tang. E = 2·38, Chord = 3·87
7/2	3·40	3·80	3·60	3·73				

(*All values to be multiplied by* 10^6 *lbs./sq. in.*)

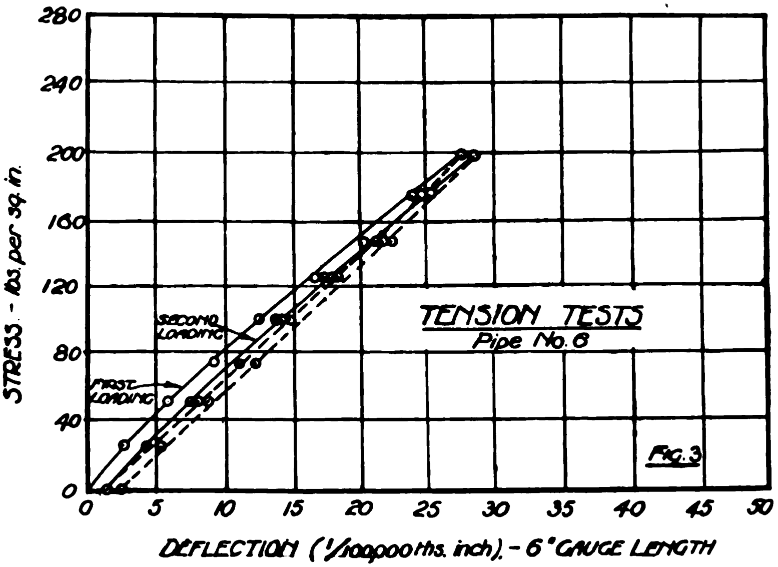


FIG. 3.

TABLE IV

SUMMARY OF RESULTS

(*All values of E are tangent values at* 200 *lbs./sq. in., and are taken from the loading curves.*)

Pipe No.	Breaking load lbs./sq. in.	Transverse *E*	Compression *Ec*	Tension *Et*	Ratio *Ec*/*Et*
1	5730	5·75	8·80	5·60	1·57
2	7515	5·56	6·95	5·66	1·23
3	6180	6·11	6·69	6·53	1·02
4	3605	4·89	5·46	3·97	1·38
5	3690	4·50	4·81	3·77	1·27
6	4410	3·99	5·73	4·09	1·40
7	3200	4·98	3·48	3·47	1·01
	Mean	5·11	5·99	4·73	
			Mean Ratio $\frac{Ec}{Et}$ = 1·27		

(*All values for E to be multiplied by* 10^6 *lbs./sq. in.*)

CONCLUSIONS.

The results of the tests are summarised in Table IV. Since the specimens were not all loaded to the same maximum, and this has a large influence on the unloading value of the modulus, only the values for loading are included. From these figures it is seen that in every case the compression modulus is higher than the tension modulus, the mean ratio being 1·27. It is doubtful whether this ratio is of sufficient magnitude or uniformity to make its inclusion advisable in the design of pipes; the correction obtained would be small compared with the unavoidable variations always found in concrete work.

As anticipated, in the transverse tests, in which the concrete is subjected to both tension and compression, the mean modulus value lies between the values for tension and compression. For individual pipes where this is not the case it is probably due to the method of measurement in the transverse tests not lending itself to such accuracy as is obtained with Lambs' extensometer and to the difficulty of allowing for variations in the cross-section of the pipe.

In the tension tests where loading was continued until fracture, which occurred at the grip, a considerable falling off in value of the modulus was apparent.

The graphs show that curves of the same form are obtained for all three series of tests, the values of the moduli in each case varying slightly with the first, second, and third loadings, a set occurring at the first loading and a smaller set at each successive loading. This agrees with curves obtained by Professor F. C. Lea in his experiments on the modulus of elasticity of concrete in compression.

THE BUILDING RESEARCH BOARD.

An account of the work of the Building Research Board during the year ended July 31, 1924, is contained in the Report of the Committee of the Privy Council for Scientific and Industrial Research (London: H.M. Stationery Office, price 3s.). When the Board was set up in 1920 the question of its continuance after an experimental period was left open for further review. It is now proposed, however, that provision shall be made for the continuance of the work of the Board for a further period of at least five years. During the year there has been a change in the Directorship of Building Research, Dr. R. E. Stradling, A.M.Inst.C.E., having succeeded Mr. H. O. Weller, who returned in January last to the service of the Indian Government.

The work of the Board during the year is summarised as follows:—

Setting and Hardening of Portland Cement.—The continuation of the investigation into what may be described as the causes of the setting and hardening of Portland cement has been the chief item in the programme of work on cements and concretes. Of the silicates and aluminates known to be present in Portland cement, pure specimens have been prepared in the laboratory of all but tricalcium silicate, the object being a study of their behaviour on hydration separately, and a comparison of the hydration of a synthetic cement made from them with that of Portland cement. Of the compounds prepared the calcium aluminates have been hydrated and a study made of the rate and products of hydration. This portion of the work forms a basis for the investigation into the properties of high alumina cements. Physical tests on the last named carried out at the Building Research Station and under Professor Lea at Birmingham University during the last year seem to indicate that these products have variable characteristics which call for chemical investigation and further tests.

Consistency of Concrete.—A great deal of work has been done on the effect of consistency on the strength and permeability of concrete, and the effect of various factors in the mixing of concrete on its permeability has been considered.

Calcium Sulphate Cements.—With the aid of a grant from the Board, Mr. C. L. Haddon, M.Sc., and Mr. M. A. W. Brown, B.Sc., carried out, in the laboratories of Messrs. Swan, Hunter and Wigham Richardson, an investigation into the setting of calcium sulphate cements, and the influence on the rate of setting of the addition of various salts to such cements.

Pozzolanic Cements.—Some experiments on the use of spent oil shale gave ground for the belief that a satisfactory pozzolanic cement could be made from this material. Later experiments, however, have thrown some doubt on this conclusion, and it appears unlikely that the average sample of the material will give such highly favourable results as were obtained with the first samples. Further inquiries are being made in this direction.

Spun Concrete.—A series of tests to determine the modulus of elasticity of "spun" concrete, with special reference to the modulus in tension, has been completed, and is given in full in this issue (p. 709).

Statically Indeterminate Structures.—A grant has been made to Professor F. C. Lea to assist him in the examination of the deflection under load of full size statically indeterminate ferro-concrete structures.

Blast-Furnace Cements.—The work which has hitherto been carried out at Bradford Technical College under the supervision of Dr. R. E. Stradling on the behaviour of Portland blast-furnace and other cements, etc., under heating tests, has been transferred to the Building Research Station, Acton, on his appointment as Director of Building Research. While the results obtained are not yet final, the work seems to point to the fact that a fire-resisting cement may be made by the addition of suitable pozzolanic substances to Portland cement, and further that with certain aggregates these cements may be employed to form concrete with fire-resistant properties. Further work with a view to evolving a fire-resistant type of ferro-concrete structure will be carried out. Dr. Stradling has also begun work at Acton on the micro-structure of Portland cement clinker, and on the effect of moisture content and the changes of moisture content on the properties of building materials.

Standard Specifications for Building Materials.—The Board is keeping in mind the question of revising existing standard specifications for building materials, or of bringing out, wherever desirable, specifications where none at present exists. To facilitate this work a suggestion has been made to the British Engineering Standards Association that a Sectional Committee of the Association be set up to deal with specifications for building materials generally. The suggestion is now under consideration by the Association.

BOOK REVIEW.

Calcareous Cements—Their Nature, Manufacture and Uses. By Gilbert R. Redgrave and Charles Spackman.

London : Charles Griffin & Co., Ltd., price 25s. net.
Third Edition

We welcome a third edition of one of the earliest textbooks on cement. The authors are well known in the cement industry, and their ability to draw on their personal experience in describing the manufacture and testing of cement adds greatly to the interest and value of the book. It is of distinct value to read of a method of chemical analysis that "We ourselves have always employed this method," and statements prefaced by "Our own experience" acquire an added interest.

Perhaps the most prominent feature of the work is its wealth of historical data, and the reader is able to follow not only the development of the cement industry but of the various kilns and other plant used in the manufacture and the improvement of the methods of testing the finished product. The statement, "We remember in the early 'sixties," is an indication of the unique equipment possessed by the authors for dealing with the history of an industry with which they were concerned as long as sixty years ago.

The course is followed of describing the manufacture of lime and tracing the development of Portland cement therefrom. The subject of chemical composition is then dealt with, followed by descriptions of the processes of manufacture and the kilns and machinery used therein, and concluding with the methods of testing. As already indicated, each part of the subject is fully dealt with from the historian's point of view, so that a complete record is presented of the growth and improvement of the manufacture of cement.

There are several chapters calling for special comment and among these is that on the chemical analysis of raw materials, which forms an instructive guide for cement works chemists, based as it is on the authors' own experience. The chapter on the theory of the constitution and setting of cement gives an admirable summary of present-day knowledge of this difficult and controversial side of the subject, and again on the more scientific side there is an excellent survey of the behaviour of Portland cement concrete in sea water. We can endorse the conclusion reached that "it seems fairly certain that it is only porous and imperfectly mixed cement concrete which suffers from the injurious attacks of the salts in sea water, and that dense and sound concrete with proper proportions of aggregate may be regarded as entirely reliable."

In practically all respects the information given is quite up to date, but the inclusion of more modern data concerning the chemical composition and quality of Portland cement would have been preferable. The clinker analyses are dated twenty years ago and the composition indicated by these is such as would not produce cement equal to the modern standard of quality. In addition, there does not appear to be any indication of what strength a well manufactured cement should possess, all the tests referred to representing the practice of many years ago.

It will be concluded from the title that the book treats not only of Portland cement, although this material naturally occupies the bulk of the space, but of other binding materials such as limes and gypsum cements, and those who are interested from the constructional standpoint have before them a complete treatise.

Cement manufacturers will find much of interest in the book, as it is but rarely one can find a record of another manufacturer's actual experience in the industry, while as a guide to any desiring to obtain a sound knowledge of the subjects dealt with the work can be well recommended.

DESIGN OF FORMWORK FOR REINFORCED CONCRETE CONSTRUCTION.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

III.—THEORETICAL DESIGN OF FORMS.

Designing for Vertical Loads.

THE vertical loads to be designed for are the weight of the concrete and the live load on the floor. The different members entering into the forms will be sheathing or lagging, joists, ledgers or girts carrying the joists, and posts. The formulæ for calculating the size and spacing of these members will be given so that the general principles of design may be understood and special cases worked out quickly.

For ordinary conditions, however, the sizes and spacing can be taken directly from tables based on these formulæ.

For members subject to bending, the four considerations are: (1) strength to resist bending moment; (2) strength to resist horizontal shear; (3) maximum allowable deflection; and (4) minimum allowable bearing on support.

The design will also depend on whether the member is a single span or extends over more than two supports. A member that has one or more supports in its length in addition to the end supports is stronger for the same load than if it were simply supported at the two ends only, because the bending moment and deflection will be less.

The design of the posts will depend on their height and size and on the crushing of the grain of the timber supported.

Symbols.

In the formulæ here given the following symbols will be used:—

w = uniform load per lineal ft. in lbs. (dead + live).
w' = uniform load per sq. ft. in lbs. (dead + live).
P = concentrated load in lbs.
p = pressure in lbs. per sq. ft.
p' = pressure in lbs. per lineal ft.
l = span in ft.
b = breadth of member in inches.
d = depth of member in inches.
s = spacing of member in inches.
D = deflection of member in inches.

E = modulus of elasticity in lbs. per sq. in.
M = bending moment in inch pounds.
M_r = resisting moment in inch pounds.
f = maximum fibre stress in lbs. per sq. in.
v = horizontal shearing stress in lbs. per sq. in.
V = total shear at end of a member.
I = moment of inertia in ins.^{4} = $bd^3/12$.
h = height in ft.

Bending Moment.

It is usual practice to design members as partially continuous when they extend over more than two supports, taking the bending moment as $M = wl^2/10$ for uniform load ; and if the member is simply supported on two supports only as $M = wl^2/8$. Floor, wall, and column sheathing will always be partially continuous.

Ledgers carrying joists and wales supporting studs are also usually designed as partially continuous, as generally long timbers are used with intermediate supports.

Joists and column yokes are simply supported as a general rule. It will be seen that one bending moment is eight-tenths of the other. If the loads are concentrated, as with ledgers and wales, it is still close enough to assume that the bending moment for a continuous member is eight-tenths that for a member supported at two points only.

Bending.

The first consideration is strength in bending, although this will not always govern the size of a member.

The bending moment on a member must equal its resisting moment or $M = M_r$, and, from the fundamental formula for bending, $M_r = \frac{I.f}{d/2}$.

So for *uniform load and single span* $\frac{wl^2.12}{8} = 1200.\frac{bd^3}{12}.\frac{2}{d}$.

For given size of member, maximum span $= l = \sqrt{\frac{133{\cdot}33\, bd^2}{w}}$. (1)

For given span and width of member, $d = \sqrt{\frac{wl^2}{133{\cdot}33.b}}$. (2)

For *uniform load and continuous span,* $M = \frac{wl^2.12}{10} = 200\, bd^2$

and we have $$l = \sqrt{\frac{166{\cdot}67\,bd^2}{w}} \quad . \quad (3)$$

$$d = \sqrt{\frac{wl^2}{166{\cdot}67.b}} \quad . \quad (4)$$

Spacing: $w = sw'/12$,

and for *single spans*, $$s = \frac{1600\,bd^2}{w'.l^2} \quad . \; . \; . \; . \quad (5)$$

and for *continuous spans*, $$s = \frac{2000.bd^2}{w'.l^2} \quad . \; . \; . \; . \quad (6)$$

Horizontal Shear.

The load carried by a member is transmitted to the supports, where it causes a shearing action on the member tending to tear the fibres apart. If the load is symmetrical the shear at each support will be half the total load on the member. On short spans and with heavy loads, where only a small depth is required for bending, it will often happen that the member will not be strong enough to resist shearing, and so the size has to be increased to allow a safe unit shearing stress.

The unit shearing stress $v = 1{\cdot}5.V/bd$ . . . . (7)

with $v = 200$, size of member required, $bd = \frac{1{\cdot}5\,V}{200}$ . . . . . . (8)

Spacing for shear, for joists with uniform load, $w = sw'/12$, and

$V = wl/2$, substituting in 8, $s = \frac{3200\,bd}{w'l}$ . . . . (9)

Deflection.

The deflection of form members must be limited or there would be wavy lines on the concrete, cracks in finished floor surfaces, etc. When the depth required for bending is small, the allowable deflection will usually govern the size to use. This is particularly the case with sheathing.

For *uniform load and single span*, $D = \frac{5}{384}.\frac{w}{12}.\frac{(l{\cdot}12)^4}{E.I.}$ . . . (10)

For *joists*, substituting $I = bd^3/12$, $E = 1{,}200{,}000$, $w = \frac{sw'}{12}$ and s

from 5, $D \text{ (in ins.)} = \dfrac{0{\cdot}03\, l^2}{d}$ . . . . (11)

If D is limited to $\frac{1}{8}$ in., max. span l (in ft.) $= 2{\cdot}04\sqrt{d}$ . . (12)

If D is limited to $l/360$ in., max. span l (in ft.) $= 1{\cdot}111d$ . . (13)

For continuous spans, the deflection can be assumed as the average of the deflection for a beam with fixed ends and a beam simply supported.

For *uniform load and continuous span*, $D = \dfrac{3}{384} \cdot \dfrac{w}{12} \dfrac{(l12)^4}{EI}$ . . (14)

For *sheathing*, $D = \frac{1}{8}$ in., l (in ft.) $= 10{\cdot}25 \sqrt[4]{\dfrac{d^3}{w}}$ . . (15)

For *joists*, substituting as before, giving s value from 6,

$D = 0{\cdot}0225 \dfrac{l^2}{d}$ . . . . (16)

If D is limited to $\frac{1}{8}$ in., max. span l (in ft.) $= 2{\cdot}357\sqrt{.d}$ . . (17)

If D is limited to $l/360$ in., max. span l (in ft.) $= 1{\cdot}481.d$ . . (18)

SPACING FOR DEFLECTION:

$D = \frac{1}{8}$ in., *single spans*, $s = \dfrac{6667\, bd^3}{w'l^4}$ . . . . (19)

continuous spans, $s = \dfrac{11112\, bd^3}{w'l^4}$ . . . . (20)

$D = l/360$ *single spans*, $s = \dfrac{1778\, bd^3}{w'l^3}$ . . . . (21)

continuous spans, $s = \dfrac{2963\, bd^3}{w'l^3}$ . . . . (22)

Bearing.

The ends of joists and ledgers must have sufficient area of bearing on their supports to prevent the crushing of the grain of the timbers. Joists will rest on ledgers nailed to the beam sides and centre span ledgers will rest on posts, and the size of these supports will depend on the allowable unit crushing stress across the grain, which = 400 lbs. per sq. in.

If V is the shear at the end of a member, or the load transmitted to the support, then for *ledgers carrying joists*,

$$\text{thickness of ledger} = \frac{V}{400\,b} \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

for *posts carrying ledgers*,

$$\text{area of bearing on post} = \frac{V}{400} \quad . \quad . \quad . \quad . \quad (24)$$

Concentrated Loads.

The above formulæ will not apply when the load is concentrated on a member at one or more points, as is the case with ledgers carrying joists.

The maximum bending moment will occur when there is a load at the centre of the span and the maximum shear when the load is at the edge of the span. For one load $M = Pl/4$.

The *bending moment* is calculated as follows for 5 concentrated loads s ft. apart (*Fig.* 1) :—

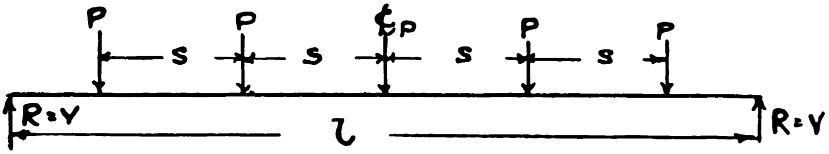


FIG. 1.

Load carried by supports $V = 5P/2$.

$$M \text{ at centre} = \frac{5P}{2} \cdot \frac{l}{2} - P.2s - Ps, \text{ or } M = P(5l/4 - 3s).$$

For three joists only, $M = P(3l/4 - s)$; and for seven joists, $M = P(7l/4 - 6s)$, and so on.

If the member is continuous the bending moment can be calculated in the above manner and then multiplied by $\frac{8}{10}$.

Having found the bending moment, this is equated to the moment of resistance of the member as before, or $M.12 = 200\,bd^2$ . . . (25)

The *shear* is calculated, assuming one joist will be at the edge of the support, as follows (*Fig.* 2) :—

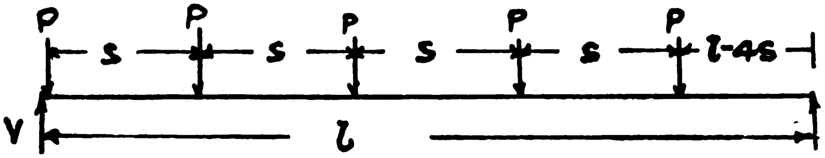


FIG. 2.

$$V = P + \frac{P(l-s)}{l} + \frac{P(l-2s)}{l} + \frac{P(l-3s)}{l} + \frac{P(l-4s)}{l}, \text{ etc.} \quad (26)$$

and unit shearing stress $v = 1{\cdot}5\ V/bd$ as before.

The *deflection* of beams carrying concentrated loads is more difficult to calculate than with uniform loading. An approximation is close enough for ordinary purposes.

For *single load and single span*, (load at centre) $D = \frac{Pl^3}{48EI}$ . . (27)

For *single load and continuous span* (approx.) $D = \frac{5{\cdot}Pl^3}{384EI}$. (28)

For TWO LOADS SYMMETRICAL ABOUT CENTRE LINE,

for *single span*, $D = \frac{Pa}{24EI}(3l^2 - 4a^2)$. (29)

for *continuous span* (approx.) $D = \frac{5Pa}{192E.I}(3l^2 - 4a^2)$. . (30)

Therefore, by combining the above two cases, we have approximately, for any number of loads, adding the deflection produced by any pair of loads equidistant from the supports to the deflection due to a centre load (*Fig.* 3) :—

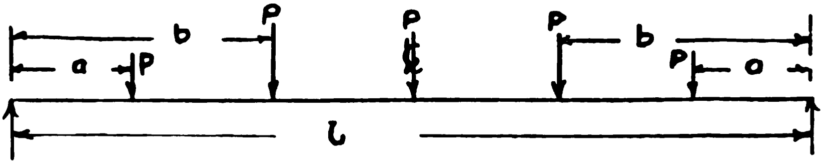


FIG. 3.

$$\textit{Single spans, } D = \frac{P}{48EI}(l^3 + 2a(3l^2 - 4a^2) + 2b(3l^2 - 4b^2) + \text{etc.}) \quad (31)$$

$$\textit{Continuous spans, } D = \frac{5}{384}\,\frac{P}{EI}\,(l^3 + 2a(3l^2 - 4a^2) + 2b(3l^2 - 4b^2)\ \text{etc.}) \quad (32)$$

In above formulæ l, a, b, must be in inches.

Posts.

The load carried by the posts is easily calculated. It is assumed, with uniform load, that half the load carried by a member is transmitted to the post at each end, though this is not strictly true when the member is continuous over two spans or more, but the approximation is close enough. With concentrated loads one load should be placed over the post, and the load will be, for 1 span = V from formula 26; for centre post of 2 spans load = $2V - P$.

Special cases may arise where the member is cantilevered out beyond the post; in an extreme case the post might carry the whole load from the cantilever and also the adjoining span, but this is so rare in form building that it will not be considered. Deflection is so great with cantilevers that they should not be used.

Maximum safe load on post, $W = 1000(1 - h/80d).bd$ . . . (33)

The height "h" and least dimension "d" of post must first be assumed. The height may be the full height of the post, but more often half the full height, since posts above about 8 ft. high should be braced both ways at the centre.

Having found the safe load the post will carry, the crushing stress on the timber carried must be investigated, as this will usually govern.

The cross-sectional area of the post "bd" multiplied by 400 (the allowable unit stress) will give the total load that can be carried without crushing the fibres of the member supported.

This allowable unit stress is about half that allowed by formula (33) for ordinary conditions, and so not more than about half the load that a post would carry should be put upon it unless hardwood caps or wedges are inserted between the member and the top of the post and between the bottom of the post and the sill on which it rests, in which case the allowable unit stress across the grain may be increased to 600 lbs. per sq. in.

Designing for Horizontal Pressures.

The foregoing formulæ for the size and spacing of members are also applicable to the design of members under horizontal pressure, such as column and wall forms, but the loading will be different.

Column Forms-Sheathing.

As seen in Part 2,* the pressure at any point will depend upon the height of the column.

If w in lbs. is the weight of an equivalent fluid causing hydrostatic pressure (obtained from previous chapter), p the pressure in lbs. per sq. ft., and h the distance of any point below the top of the column, then

$$p = wh. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (34)$$

It is assumed for simplicity that the pressure will be uniform between yokes and of an intensity equal to that at the lower yoke ; this assumption is on the safe side.

As the sheathing will be continuous and the load assumed uniform, the bending moment can be taken as $M = ps^2/10$, where s is the spacing of the yokes (in ft.). Formulæ (3) and (4) will then apply with ps in place of wl.

The maximum span for a deflection of $\frac{1}{8}$ in. is given by formula (15) with "wh" in the place of "w." This will also be the maximum spacing of the yokes.

Yokes.

The total pressure per lineal foot on any yoke will be the pressure at the centre of the yoke multiplied by the spacing of the yokes at that point (approximately).

If this total pressure is p', $p' = ps = whs$ . . . . (35)

This pressure will not extend over the whole yoke, since the span of the yoke will always be greater than the dimension of the column by an amount varying with the detail of construction, but will generally be about 12 in., that is (*Fig.* 4), $l - k = 12$ in. (approx.).

Unless the columns are very wide, say 5 ft. or over, requiring an intermediate bolt (*Fig.* 5), the yoke will be simply supported. Since the pressure does not extend over the whole span, and since the proportion of the span under pressure is variable with the size of yoke used, there is some difficulty in giving general formulæ and tables without making an assumption. However, $l - k$ varies within small limits, say from 8 in. to 14 in., and it is sufficiently close to assume a constant value of 12 in. ; that is, the yoke can be assumed to be 12 in. longer than the dimension of the column. This enables us to write a simple general formula for the bending moment,

---

* *Concrete and Constructional Engineering*, October, 1924.

$$k = l - 1,\ p' = whs,\ M = \frac{whs}{8}(l^2 - 1) \quad . \quad . \quad . \quad (36)$$

If a centre bolt is used the bending moment on each half of the yoke would be a little less than given by the formula (36) (l in this case would be half the total span), but since columns of such width as to require a centre bolt do not often occur it is not worth while making a special case of this, as the spacing of the yokes would only change an inch or so.

A higher unit fibre stress can be allowed for column yokes, since there is no uncertain live load as on floor joists, nor is there the same vibration and impact, so we will assume the safe unit fibre stress as 1600 lbs. per sq. in. instead of 1200.

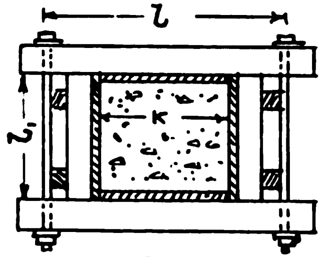


Fig. 4.

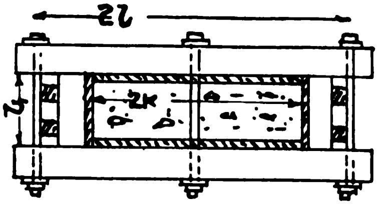


Fig. 5.

Bending.—Equating the bending moment to the moment of resistance,

we have
$$\frac{whs}{8}(l^2 - 1).12 = \frac{1600.bd^2}{6}$$

$$w = 125, \text{ and spacing } s \text{ (in ins.)} = \frac{17{\cdot}06\,bd^2}{h(l^2 - 1)} \quad . \quad . \quad . \quad . \quad (37)$$

This will give the spacing of the yokes in inches for any size yoke and depth below top of column and for any column width, remembering to take l one foot greater than the dimension of the column.

Horizontal Shear.—The end shear $V = whsk/2$, with a centre bolt

$$V = \frac{whs(l^2 - 1)}{4l}$$

unit shearing stress for single span, $v = \dfrac{1{\cdot}5whsk}{2bd} \quad . \quad . \quad (38)$

unit shearing stress for continuous span, $v = \dfrac{1{\cdot}5whs(l^2 - 1)}{4l.bd} \quad . \quad (39)$

Deflection.—The deflection can be found from formula (10) approximately, substituting *whs* for *w* and for *s* the value found from (37), and we have, for single spans, $D = \frac{\cdot 04\, l^4}{d(l^2 - 1)}$ (approx.) . . . . . (40)

If $D = \frac{1}{8}$ in., $$d = \frac{\cdot 32\, l^4}{l^2 - 1} \quad \text{. . . . .} \quad (41)$$

If $D = l/360$, $$d = \frac{1\cdot 20\, l^3}{l^2 - 1} \quad \text{. . . . .} \quad (42)$$

Usually a deflection of $\frac{1}{8}$ in. is allowed.

From these last two formulæ the maximum span for any depth of yoke may be found.

The above formulæ apply to the yokes that carry the connecting bolts. The other pair of yokes (*Figs.* 4 and 5), have a span l_1 equal to the side of the column, and this span is reduced by the wedges between the yokes and the bolts, so that the stress in them will always be less than in the long yokes and they can be made smaller if so desired.

Assuming full span l_1, the above formulæ will apply with l_1^2 put in the place of $l^2 - 1$.

Bolts.

The yokes will be held together by rods, bolts, or clamps. The tension in the bolt will equal the shear at the end of the yoke $= whsk/2$.

When bolts are threaded the effective area will be at the base of the threads; this area will be about two-thirds that of the gross area of the bar, and should be allowed for.

For threaded bolts, allowing a safe unit stress of 14,000 lbs. per sq. in. on the gross area, diameter

$$d = \sqrt{\frac{hsk}{175}} \quad \text{. . . . .} \quad (43)$$

If the bolts are upset at the threaded end, and for plain round bars, the allowable stress may be 20,000 lbs. per sq. in., and then

$$d = \sqrt{\frac{hsk}{200}} \quad \text{. . . . . . .} \quad (43a)$$

Upset bolts are seldom used.

The size of the bolt theoretically required is generally small and is not usually calculated, since less than $\frac{1}{2}$-in. diameter bolts should not be used; common practice is to use $\frac{5}{8}$-in. bolts for all columns, as they have to be sufficiently strong to withstand wedging against them without bending.

With very large columns, when a centre bolt is used, the load on this bolt should be calculated, as it may be necessary to use a ¾-in. bolt.

Washers.

Washers are necessary to distribute the tension in the bolt over sufficient area of the yoke so that the fibres will not be crushed in.

$$\text{So that area of washer} \quad = \frac{whsk}{800} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (44)$$

This will give the net area required, and to it must be added the area of the hole for the bolt.

To find the thickness required, the washer is treated as a plate cantilevering about the edge of the head or nut and uniformly loaded.

If A is difference between area of washer and area of head or nut,
d is side or diameter of head or nut,
p is projection of edge of washer beyond head or nut,
t is the thickness of washer,
w is pressure on washer in lbs. per sq. in.

Then approximately for wrought-iron or steel washers,

$$t = \frac{1}{220}\sqrt{\frac{wAp}{d}} \quad . \; . \; . \; . \; . \; . \; . \quad (45)$$

For cast-iron washers the thickness should be three times that given by formula (45). (Kidder's "Architects' Handbook.")

Theoretically the size of washer will change with the size and height of the column, but this is not practical on the job so that a size is adopted as a standard which will suit all ordinary cases.

The following rule can be used as a guide :—

For columns up to 36 in. wide or square and 12 ft. high, use 3 in. sq. by ⅛ in. washer.

For columns from 36 in. to 42 in. wide or square and 12 ft. to 16 ft. high, use 3½ in. sq. by ¼ in. washer.

For columns from 42 in. to 48 in. wide or square and 16 ft. to 20 ft. high, use 4 in. sq. by ⅜ in. washer.

With 4 in. by 6 in. or larger yokes do not use less than 3½ in. by ¼ in. washers.

Wall Forms.

Sheathing.—The design of sheathing for wall forms is the same as for column forms, although in this case the sheathing will usually span horizontally instead of vertically.

The spacing of the vertical studs will depend on the strength of the sheathing, and since the pressure will be greatest at the bottom of the wall it is only necessary to find the maximum allowable span at this point. This is found in the same way as for floor sheathing, with wh in the place of w, so

for strength, $$\text{max. } l = \sqrt{\frac{166{\cdot}67\,bd^2}{wh}} \quad . \quad . \quad . \quad . \quad . \quad (46)$$

for deflection, $$D = \tfrac{1}{8}\text{ in., max. } l = 10{\cdot}25\sqrt[4]{\frac{d^3}{wh}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (47)$$

$$D = l/360\text{, max. } l = 14{\cdot}31\sqrt[3]{\frac{d^3}{wh}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (48$$

Studs.—Since the studs can be tied and braced at any point, the spacing will depend upon the strength of the sheathing, found from the above. The thickness of the stud can be added to the spacing found from the formula for sheathing, to give the actual spacing of the studs.

The spacing will be a minimum at the bottom of the wall and is kept the same for the full height, as studs are used in long lengths and it is not practical to vary the spacing with the pressure.

Accurately to find the bending moments on the studs would be a tiresome procedure, and the result obtained would not be worth the time expended, so assumptions can be made.

The studs are supported individually by internal ties of wires or bolts, or collectively by external wales, bolted or wired through the wall.

We will assume that the pressure is constant between any one wale or tie and the one next above it, with intensity equal to that at the lower one.

As for yokes, the allowable unit fibre stress can be increased to 1600 lbs. per sq. in.

At any depth in the wall the pressure on the stud will $= whl$, where l is the spacing of the studs (*Fig.* 6).

If s is the spacing of the ties, $$M = \frac{whls^2.12}{10} = \frac{1600.bd^2}{6} \quad . \quad .$$

or, for strength, max. span s (in ins.) $$= 179\sqrt{\frac{bd^2}{whl}} \quad . \quad . \quad . \quad . \quad . \quad (49)$$

for deflection, $$D = \tfrac{1}{8}\text{ in., max. } s = 66\sqrt[4]{\frac{bd^3}{whl}} \quad . \quad . \quad . \quad (50)$$

$$D = s/360\text{ max. } s = 75{\cdot}12\sqrt[3]{\frac{bd^3}{whl}} \quad . \quad . \quad (51)$$

These formulæ will give the maximum spacing of the ties for any depth of wall and size of stud, or will give the spacing of the wales if used to support the studs.

Wales.—Wales are used to keep the forms in line, to support the studs, and to avoid the necessity of having to tie every stud. They are bolted through the wall or are braced from the outside, and transmit the load on the studs to the bolts or braces. They will be continuous members under concentrated loads, and are designed in the same way as ledgers carrying floor joists ; the same formulæ and tables will apply, but instead of the loads carried by the joist it will now be the pressure transmitted by the studs or " $whls$," approximately, h being taken to the centre of the wale being designed (see formulæ 25 to 32).

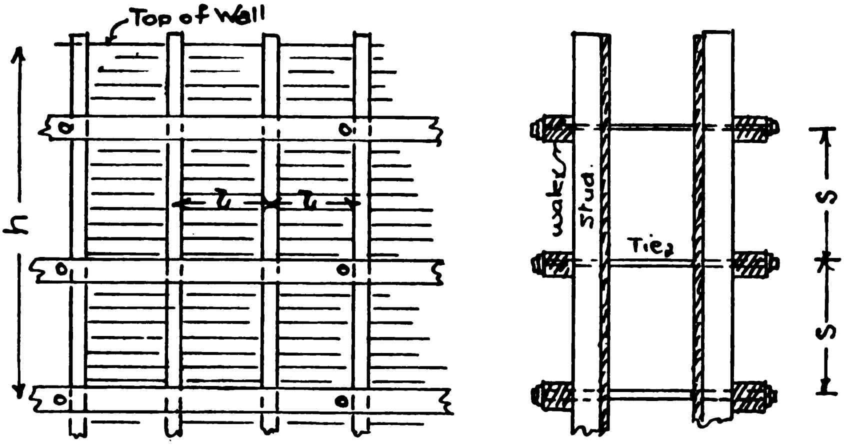


FIG. 6.

This approximate method of finding the loads on the wales is close enough for ordinary purposes, the error being less than 10 per cent., but occasions may arise when it is necessary to find a closer approximation, so the method will be given.

Calculation of loads on wales by more exact method.—The effect of continuity on the reactions at the wales will be neglected. The pressure of the concrete varies from zero at the top of the wall to a maximum at the bottom, being at any point proportional to the depth from the top, so that the pressure on a stud can be represented by a triangle (Fig. 7), aej, where ae represents the height of the wall and aj the horizontal pressure at the bottom.

If b, c, d represent the location of wales, the total pressure on the stud between any two wales, such as bc, will be represented by the area of the trapezoid $bcgh$ and will act through the centre of gravity of this area at a distance x *from* bh.

The total pressure P on bc equals the average of pressures at b and c times bc or $P = w.1.\ (cg + bh)/2)\ bc$, where 1 is the spacing of the studs.

If $ce = h'$ and $bc = h$ then $P = \frac{wlh(h + 2h')}{2}$ since $cg/bh = ec/eb$.

The centre of gravity of $bcgh$ from bh is $x = \frac{h.h + 3h'}{3.h + 2h'}$.

The proportion of the load P transferred to c is therefore

$$P.x/h = wlh.\frac{h + 3h'}{6} \quad . \quad . \quad . \quad . \quad (52)$$

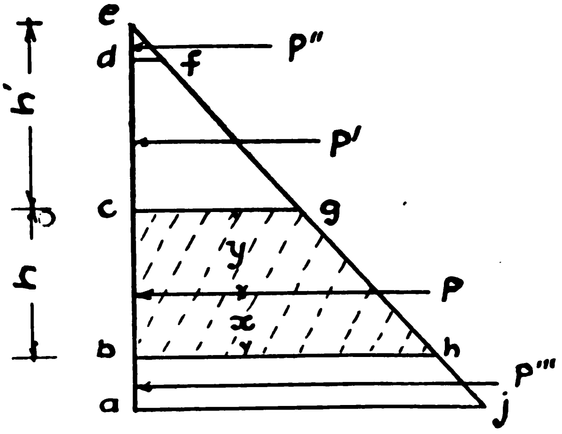


Fig. 7.

and the proportion of the load P transferred to b is

$$P.y/h = wlh.\frac{2h + 3h'}{6} \quad . \quad . \quad . \quad . \quad (53)$$

The reaction at c from P' is similarly found, and the two reactions added together give the load on the wale at c.

It is assumed that the whole load on the stud below the lowest wale is carried by that wale, and that the whole load on the stud above the highest wale is carried by that wale.

The pressure P'' on de is $wl.de^2/2$, the whole load being carried at d.

Braces.—Theoretically a wall form could be built without any external braces, because the ties take all the pressure, but the impact of the concrete would soon throw the wall out of line, so that some braces should always be used.

The distance apart of the braces is largely a matter of judgment; every 10 ft. should be sufficient if the wall is well tied.

Exterior Bracing for Walls.—When bolts or wire ties are used the bracing, as mentioned above, merely serves to hold the wall in line against the impact of the concrete. If, however, no internal ties can be used, which is often the case when large masses of concrete are to be held—as in bridge abutments, or when only one side of the wall is to be formed, which is the case when a new wall is built against an old one—then the braces must take the whole pressure and must be designed accordingly.

The braces will take the horizontal pressure on the wales. If they can be placed horizontal, that is, in line with the direction of the thrust, the load on the brace will be the same as the horizontal pressure on the wale, and the size of brace required is found from formula (33) for posts or by the allowable bearing stress on the wale, whichever gives the greater value.

It is more usual, however, that the braces are inclined, being held at the bottom by stakes driven into the ground. When this is the case the thrust on the brace will increase with the inclination of the brace to the horizontal. For angles with the horizontal of 30, 45 and 60 degrees, the thrust on the brace will be approximately 1·25, 1·5, and 2 times the horizontal pressure on the wale.

The higher the wale the greater can be the inclination of the brace, not only to save timber but because the pressure on the wale will be less. If there are three wales the inclination of the braces may be about 30 degrees for the lower one, 45 degrees for the middle one, and 60 degrees for the upper one. They are often held by the same stake.

Horizontal Sheathing.—Sometimes, though not often, wall sheathing is run vertically and the studs horizontally, in which case we have the same conditions as with columns and the forms are designed in the same way, using the formulæ for continuous conditions. In this case the wales will be vertical, but the method of design can be the same as when they are horizontal, assuming that between any two ties each horizontal stud will bring the same load to the wale as the load on the lower stud. This assumption is on the safe side and is sufficiently close, because only low walls are built in this manner and the ties should always be close together.

Wale Bolts.—Knowing the load carried by the wale, the stress in the bolt and hence its size can be found in the same way as for column yoke bolts.

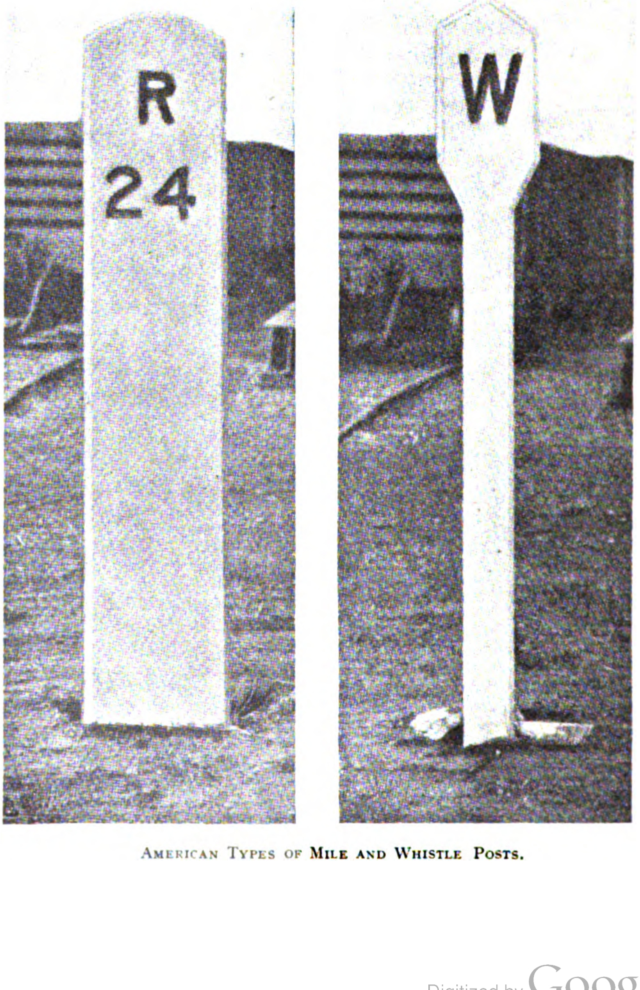
Usually not heavier than ¾-in. diameter bolts are used, so that if the calculated size is greater than this it is better to shorten the span of the wale and use smaller bolts; this is especially true if the bolts are to be pulled afterwards.

(*To be continued.*)

CONCRETE PRODUCTS.

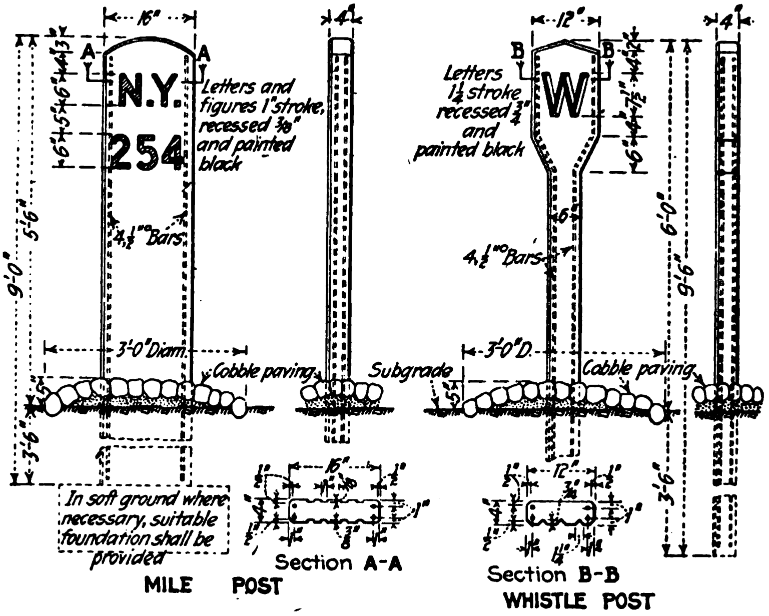
CONCRETE POSTS FOR RAILWAY USES.

The concrete mile and whistle posts illustrated on this page are in use on the New York Central Railroad, and in order to ensure maximum visibility they are made of light-coloured sands and aggregates. The posts, says "Engineering News-Record," are cast in simple forms but well made so as to be used repeatedly. For the whistle posts the "W" is recessed by nailing wooden strips to the forms. In casting the mile posts, reversed cast-iron letters and figures are secured to the forms and the recessed letters then painted black. As concrete is poured the forms are rapped with a hammer so that a dense concrete is secured and imperfections in the surface are avoided. The exposed side is trowelled to a smooth surface. It is desirable to rub the surface with a little sand and water to remove the skin coat of neat cement which the trowelling and suction of the form bring to the surface. The mixture consists of one part of Portland cement, two parts of white sand, and four parts of white gravel passing a ¾-in.



American Types of Mile and Whistle Posts.

screen. The reinforcing bars are laid in the concrete as it is poured. After the forms are removed, the posts are kept wet by sprinkling until thoroughly cured. They are ready for placing in about a month. The mile posts require four ½-in. round rods 8 ft. 6 in. long. On account of their extra length the whistle posts require four ½-in. round rods 9 ft. long.

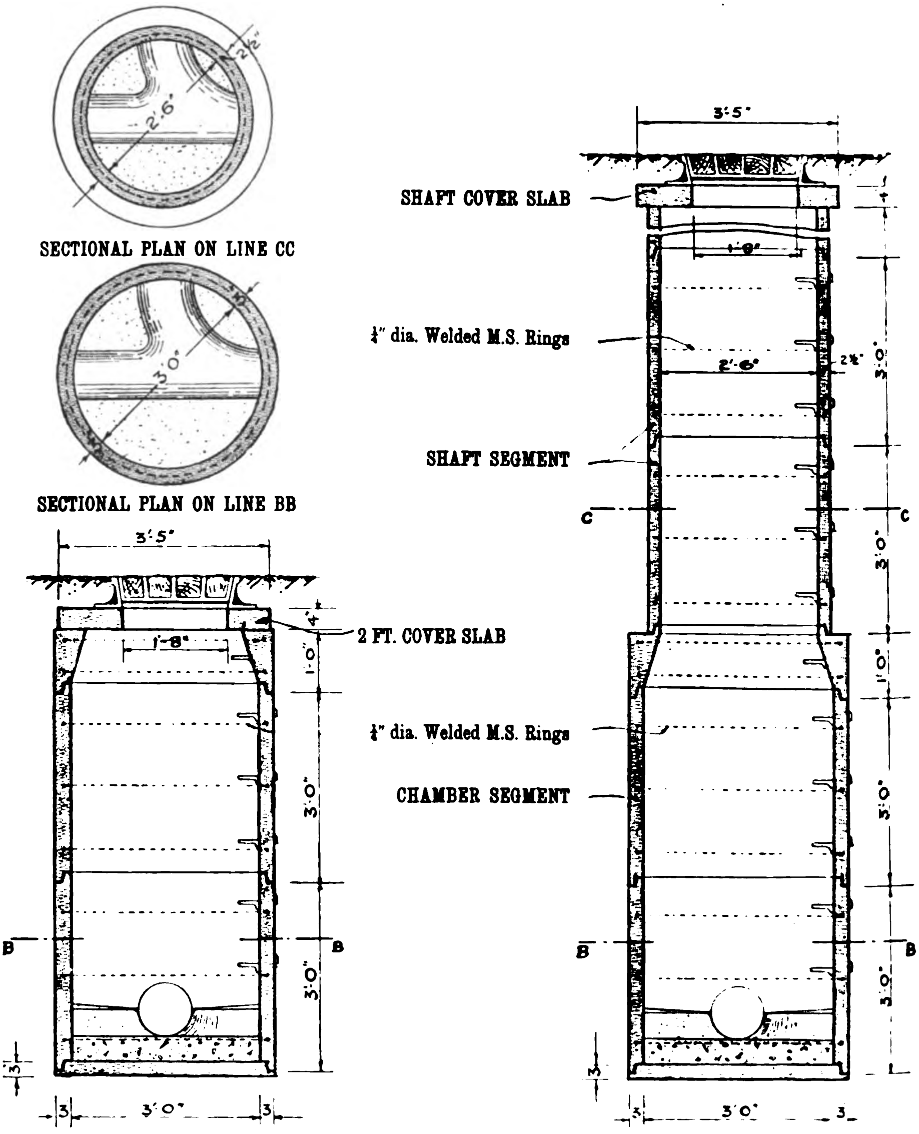

16"
4"
A
A
N.Y.
254
Letters and figures 1" stroke, recessed 3/8" and painted black
4, ½" Bars
9'-0"
5'-6"
3'-0" Diam.
Cobble paving
3'-6"
In soft ground where necessary, suitable foundation shall be provided
16"
Section A-A
MILE POST
12"
4"
B
B
Letters 1¼ stroke recessed ¾" and painted black
W
4, ½" Bars
6'-0"
9'-6"
3'-0" D.
Subgrade
Cobble paving
3'-6"
12"
Section B-B
WHISTLE POST

Elevations and Sections of American Types of Mile and Whistle Posts.

CONCRETE MANHOLES.

Their cheapness and durability, and the possibility of doing away with a large amount of site work, are factors which have been responsible for the increased use of reinforced concrete manholes, which are now being extensively used by Borough Surveyors and others all over the country. Reinforced concrete manholes are now made in different sizes by a number of manufacturers of concrete products, but even in cases where they have to be transported long distances from the concrete yard to the site where they are to be used they work out considerably cheaper than manholes built *in situ* with brick, and have the further advantages that bricklayers are not required and traffic is not disturbed for so long a period when the manhole is delivered in sections ready for placing in position.

On page 734 we illustrate the type of reinforced concrete manhole made by Messrs. Manufactured Concrete Works, Ltd., of Barnstaple, who have supplied them in large numbers to local authorities and railway companies. These manholes are all made in a standard diameter of 3 ft., and in lengths varying from 3 ft. to 6 ft. to suit different requirements. Both chamber and shafting are made in segments with ogee joints. In order to reduce the cost of handling and placing to a minimum, the heavier segments are provided with ring-bolts cast in them for lifting. We are informed that the manufacturers are in a position to deliver these manholes up to a radius of 200 miles from their works at a price less than the cost of building a brick manhole after allowing for the cost of excavation.



SECTIONAL PLAN ON LINE CC

SECTIONAL PLAN ON LINE BB

Concrete Manholes.

THE FOREMAN'S GUIDE TO CONCRETE.—II.

A MANUAL FOR ALL ENGAGED IN CARRYING OUT CONCRETE AND REINFORCED CONCRETE STRUCTURES.

By ALBERT LAKEMAN, M.S.A., M.I.Struct.E.

LOADS.

In dealing with the explanation of strain and stress reference was frequently made to the " load " or " force." Although this term is so obvious that a detailed description is not called for, it is necessary to deal with the conditions of loading, or, in other words, the kinds of loads which have to be provided for in designing. Generally speaking, the load may be divided into two types, viz. :

(*a*) The dead load of the member or part of the structure under consideration ; and

(*b*) The superimposed or external load.

The dead load of the member means the actual weight of the material composing that member. As an example, if a concrete beam 12 in. deep and 8 in. wide is resting on two walls which are 15 ft. apart, the beam must have sufficient strength to carry itself across this span, because the weight of the beam constitutes a load which is unsupported except by the walls at the ends. This may not appear to be a serious point, because there are very few materials used in structural work which are unable to support themselves in this way, but the actual weight of the member is often an important factor in the design because it forms a part of the total load to be carried and it must be added to the superimposed load to arrive at the requirements of strength.

A further example of the dead load and its influence in reinforced concrete work can be given which will appeal to every practical man. When a failure occurs in a new reinforced concrete floor during the construction of a building, or in fact in any part of a concrete structure, the accident is invariably due to the removal of the forms before the concrete has properly hardened, and in the majority of cases the work that fails is not subject to any superimposed load at the time of collapse. It is quite obvious, therefore, that the concrete is unable to support itself, or, in other words, carry its own dead load across the span owing to the lack of strength caused by insufficient maturing.

The weight of reinforced concrete is approximately 150 lbs. per cubic foot (which equals a block 12 in. high, 12 in. wide, and 12 in. long), and the beam previously mentioned as 12 in. deep by 8 in. wide and 15 ft. long would therefore have a weight of 100 lbs. for every 12 in. of its length, or a total weight of 1,500 lbs. for its length of 15 ft. This is over 13 cwts., and it will obviously be very risky to take away the props which support the concrete during the setting of the cement until the beam has properly hardened, as apart from any damage that may be caused during the removal of the supports the green concrete will sag or deflect by its own weight and the beam will be seriously weakened, even if total collapse does not take place.

A reinforced concrete floor slab 6 in. thick will weigh about 75 lbs. per sq. ft., and it will be realised that this weight or dead load will frequently be a large percentage of the total load which has to be supported.

This point can also be considered in another way which should be of assistance in pointing out the necessity for leaving the form-work in position until the concrete has sufficiently matured to justify removal. The calculations are based on the theoretical strength of the concrete at a certain age, viz. in the Regulations of the London County Council the *ultimate* compressive resistance of concrete composed of 1 part Portland cement, 2 parts sand and 4 parts coarse material is taken at 2,400 lbs. per sq. in. when it has reached the age of four months after mixing, and the *working* stress under ordinary circumstances is limited to 600 lbs. per sq. in. Now, the concrete when first mixed and placed in position is a plastic material without any strength to resist compression, and from this stage it gradually develops strength until it reaches a condition, after four months, when it will safely carry the total load for which it has been designed. The total load, however, includes the dead weight of the concrete itself, and it will be quite obvious that it must have reached a certain stage in the development of its strength where the resistance is sufficient to carry safely that portion of the load represented by this dead weight before the forms are removed, as the safety then depends entirely on the strength of the material.

The time for the removal of the forms will, of course, depend on the weather and other factors, and the man in charge of the work must look to the architect or engineer for guidance and instructions, but at the same time accidents would be avoided if the foreman will always realise that the weight of the concrete is part of the load and load in excess of capacity means failure.

The superimposed or external load means the weight or pressure which the member or part of the structure has to carry or support, and the amount of this will of course vary according to circumstances. In the case of a floor slab the superimposed load will be the weight of the articles placed on the slab when the building is in use, and this is generally assumed by the designer in accordance with regulations or rules laid down. For example, if the floors are intended for hotel bedrooms the superimposed load may be taken as low as 84 lbs. per sq. ft., while in the case of a warehouse the load allowed for in the design may be 224 lbs. per sq. ft. The writer has designed factory floors where the load to be carried was fixed at 1,140 lbs. per sq. ft., although this is exceptional, and generally speaking the load on a warehouse or factory will be somewhere in the neighbourhood of 230 lbs. per sq. ft. for all ordinary purposes.

The total load that has to be provided for in the case of a floor slab is therefore the weight of the materials used in the construction of the floor added to the weight of the articles that it is assumed will be carried by the floor.

In the case of floor beams the total load will be the weight of the beam itself added to the weight of the slab and the superimposed load carried by the slab, as will be explained later.

A beam carrying a wall will be called upon to support the weight of the wall together with any loads which may be supported by the wall above the beam, together with its own weight.

When dealing with roofs the load or pressure to be considered will include pressure due to the wind blowing against it if it is a pitched roof in addition to the weight of the roof construction, and roofing material such as slates, tiles, etc.

There are many factors to consider and many allowances to make, and the designer is in some cases called upon to go into many calculations when the structure is complicated before the correct allowance for the load or pressure can be determined.

The methods of calculation are outside the scope of these notes, as it is not intended to show how to design the parts of a reinforced concrete structure but to explain the points which have to be considered and the different terms in use.

In addition to the division of the load into the two types as given above, mention must be made of what is known as a " live " load, or moving load. Generally speaking the superimposed load in pounds per square foot will be considered as a stationary load, but in some cases the load may be caused by moving machinery, which means that vibration or shock has to be provided for and some special allowance is made for this. The allowance made is generally 50 per cent. in excess of the actual load. As an example, if a machine is a moving one and the actual weight is 1,000 lbs., then the load value used in the calculations will be 1,500 lbs., as the extra 500 lbs. will provide for the increase in stress caused by the movement. This point is of importance as illustrating the risk of damage that is caused by dropping materials or heavy weights on to a newly-constructed concrete floor, as the shock is liable to cause a greater stress than that produced by placing the same article down carefully.

Having considered the types of load or force in a general way we can proceed to deal with the different ways in which the load is applied to the structure. Sometimes the load to be carried is concentrated in one spot, as, for example, when the end of one beam rests on another or where a column is supported by a beam without another column immediately below, while in other cases the load is spread more or less evenly over the whole surface of the supporting member, as occurs when a wall is built on a beam for the full length of the latter, or a warehouse floor is covered by goods stored over the whole area of the floor. It is seldom that the load is uniformly distributed over the whole area of a floor in practice, but in making the calculations this is assumed as the condition that has to be provided for as the positions of gangways and open spaces will be subject to change, and it is necessary to ensure a uniform strength throughout to allow for the load at any point.

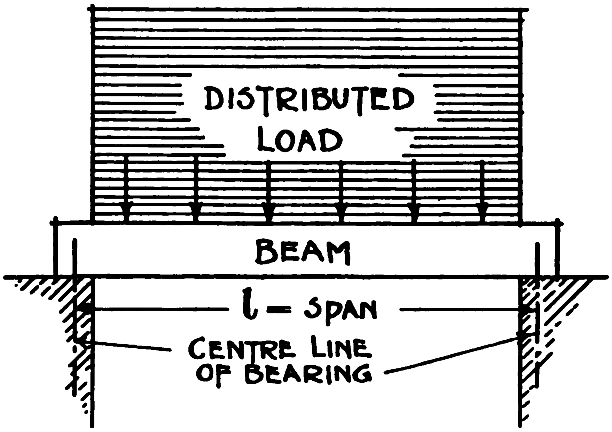


FIG. 13.

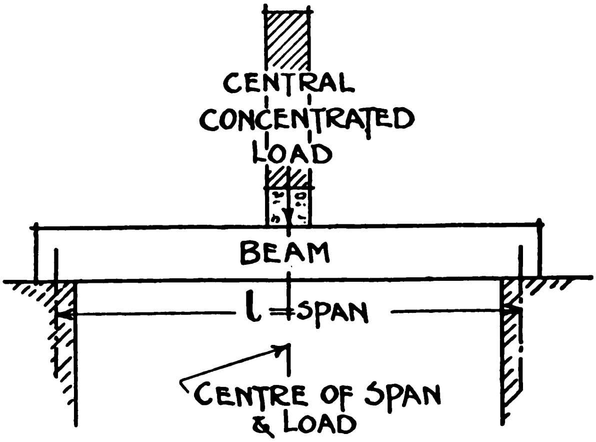


FIG. 14.

The two methods of loading that have to be provided for are known therefore as "concentrated" and "distributed" loads, and in some cases a member will have to support a combination of the two, being subject to a distributed load and in addition having to carry one or more concentrated loads at certain points.

When a beam or floor slab is supporting a load the latter is tending to cause the member to bend, and the extent of this tendency is calculated; the result of these calculations is known as the "bending moment." This expression will be explained in detail later, but the word "moment" means "amount," and "bending moment" expresses the amount of bending tendency which has to be provided for by the resistance of the beam or slab. This amount will depend on the load and also on other factors, but for the time being the load only is being considered.

The most simple case of loading is that of a uniformly distributed load over the whole of the member, as shown in *Fig.* 13, where a beam supported at each end carries, for example, a plain brick wall marked as the distributed load. The tendency to bend the beam or cause stress is dependent on the amount of the load, the nature of the load, the conditions at the ends of the beam, and the length or span of the beam. If all these factors are considered and the tendency to cause stress is found to be any figure, say, for example, 10, a comparison can be made with other conditions of loading.

The next case will be that where the load is concentrated in the centre of the length or span of the beam, as shown in *Fig*. 14. In this example the wall is indicated as built on another beam at right angles so that the whole of the load is concentrated at the one point. Now, if the total concentrated load is equal in amount to the total distributed load as shown in *Fig*. 13, and all the other conditions are the same, the tendency to cause stress would be, by comparison, 20, or twice as much with the central concentrated load as with the distributed one.

Two other examples are given in *Figs*. 15 and 16. In *Fig*. 15 the weight is shown as a wall distributed uniformly over the length of a cantilever, or beam supported at one end only, and here the tendency to cause stress, if all other conditions are equal, will be 40, or twice as much as that for *Fig*. 14 and four times as much as that in *Fig*. 13. In *Fig*. 16 the load is indicated as being concentrated entirely at the outer end of the cantilever, and with all other conditions being equal the tendency in this case will be 80, or eight times as much as that in *Fig*. 13.

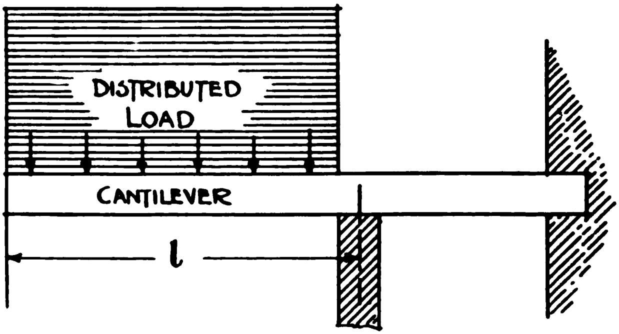


FIG. 15.

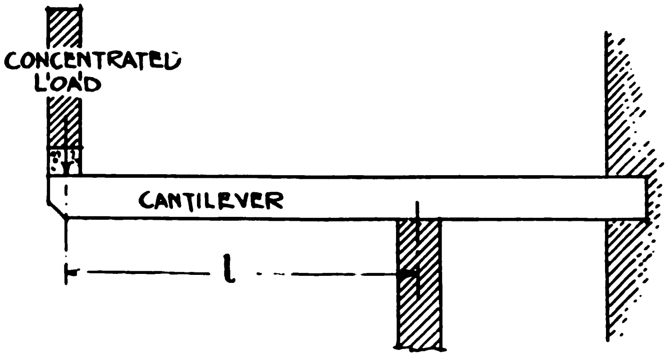


FIG. 16.

This will indicate in a general way that the same load placed in different positions will cause different amounts of stress, and the foreman will appreciate the necessity of using his judgment when arranging for the stacking of heavy materials on work already executed.

It is quite a frequent matter to find large quantities of brick, stone, or other materials piled together in the centre of a slab or over the centre of a beam without sufficient regard to the possible effect on the structure, while ample storage space near columns or walls is neglected. When placing heavy articles or materials on to recently executed work it is also quite simple in many cases to distribute the load over a considerable area by the judicious use of timber or other bearing medium, which not only protects the actual surface but also spreads out the load.

The effect of concentrated loads at intermediate points in the length of a beam has not been dealt with because this value cannot be expressed in a simple manner as a comparison with the other methods of loading, but this matter can be considered later on if necessary. As a general rule for guidance, however, it may be stated that the tendency to cause stress with a concentrated load becomes less as the load is moved towards a support. When dealing with the erection of form-work for beams and floor work immediately above recently placed concrete it is necessary to provide sole plates under the feet of props or struts, and the need for avoiding vibration and getting the maximum distribution of the weight that will be placed on the new forms can be realised from the foregoing notes.

RESISTANCE TO LOAD.

The general principles and types of loading having been considered we can now deal with the materials, and the points which influence the designer when calculations are made for the necessary resistance to the loads that require to be carried by the structure.

The resistance to the load is provided by the strength of the two materials employed in the construction, viz. concrete and steel, and as these act together it is necessary to understand how this action takes place; this can be explained after dealing with the points affecting each material separately.

CONCRETE.

The bulk of the structure will be composed of concrete, and the proper manufacture of this material is so important that it cannot be impressed too strongly on the person in charge of the work. It is not proposed, however, to deal with the correct methods of gauging, mixing and placing of concrete or the points to be considered in the selection and approval of the sand and coarse material as these matters are outside the scope of these notes.

As previously mentioned, the part played by the concrete is to provide resistance to compression, and to do this successfully it must come up to the expectations of the designer who allows for a minimum resistance based on experience and tests made by various authorities. In all reinforced concrete calculations the designer works in pounds and inches, as these units are the most convenient and give the maximum accuracy. The allowance generally made for concrete in compression is 600 lbs. per sq. in., and this is known as the " safe working stress." In the Regulations of the London County Council it states that concrete composed of one part cement, two parts sand, and four parts of coarse material shall have an ultimate compressive resistance of at least 2,400 lbs. per sq. in. four months after mixing, while the ultimate compressive resistance one month after mixing shall not be less than 1,600 lbs. per sq. in. The word " ultimate " as here used means the point at which the concrete will actually fail or be crushed as distinct from the working resistance, which must be much less to provide for safety. The resistance specified in the regulations is one that can be reasonably expected with good concrete, and the designer in making his calculations is always using a value for the strength of the material which is based on good work; he is thus assuming that the foreman will not fail to do his part during the execution in the field.

FACTOR OF SAFETY.

It will be seen that the safe working stress on the concrete in compression is taken as 600 lbs. per sq. in., whereas the pressure required to cause failure when the material has been made four months should be at least 2,400 lbs. per sq. in. This indicates the difference between the working stress and the ultimate strength, and this difference is due to an allowance being made under what is known as the " factor of safety." The factor of safety in this case is four, because the load necessary to cause failure is four times as much as that which will be allowed on the concrete. This factor of safety is affected by other considerations, as will be mentioned later, but it can be taken that the factor of safety is the value which is given by dividing the ultimate strength by the working stress, viz. $\frac{2,400}{600}$ equals 4.

It is the usual method to find the ultimate strength of a material by actual test and then decide on a factor of safety necessary according to whether the material is reliable or not, and when this factor has been decided the ultimate strength is divided by it to give the working or safe stress. The factor of safety may therefore be defined as the figure which shows the ratio between the breaking stress and the working stress.

The actual ratio or relation of the breaking stress to the working stress in the structure will depend on the quality and accuracy with which the work is executed, and by carelessness or indifference it is possible for the workmen to reduce the factor of safety, in spite of the most careful design.

It will be noticed that the strength of the concrete at the age of one month should not be less than 1,600 lbs. per sq. in. in compression, and this means that it would not be safe to allow the full load to be applied at this stage, or the ratio between the breaking strength and the working load would not be sufficient to give the necessary margin for safety. The strength of concrete increases with age, and generally speaking 90 days after mixing is the minimum time that should be allowed before the full working load is applied.

When the concrete is specified to be richer than the ordinary 1 : 2 : 4 mix it usually means that the designer has been calculating on a higher working stress than 600 lbs. per sq. in., as the strength of the concrete has been increased in order to reduce the volume required. As an example, in the Regulations of the L.C.C. it provides that where the concrete is made with two parts cement, two parts sand, and four parts coarse material the working stress can be taken as high as 750 lbs. per sq. in. if the breaking strength four months after mixing is not less than 3,000 lbs. per sq. in. This indicates the necessity for working strictly to the specified proportions, because the designer is relying on a certain minimum strength and it will be disastrous if he calculates on a specially strong concrete according to the specification and the foreman and clerk of works do not see that this special strength is provided.

Although it is not proposed to deal with the actual mixing of the concrete in these notes attention may be called to the necessity for using the correct amount of water. The ideal quantity of water required cannot be specified exactly because it will depend on the nature of the aggregate, the atmospheric conditions, and the nature of the work, but it is seldom realised by the man in charge of the mixer that the strength of the finished concrete will be considerably reduced by the use of too much water, and in addition, an excessively sloppy concrete leads to other defects and waste.

(To be continued.)

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	„	14	0
„ „ ½ in. mesh	„	15	0
Best British Portland Cement	per ton 58s. to	63	0
"Ferrocrete" Portland Cement	10s. per ton extra		

BOARDING FOR SHUTTERING—

		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	„	29	6	33	6
1½ in.	„	35	6	41	0

SAWN TIMBER FOR STRUTS AND SUPPORTS—

3 in. by 4 in.	from £24 10s. per standard
3 in. by 6 in. and 3 in. by 7 in.	„ £25 10s. „ „

MILD STEEL RODS FOR REINFORCEMENT—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13	0
7/16 in. to ½ in. Rounds	„	13	6
⅜ in. Rounds	„	14	6
¼ in. Rounds	„	15	6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

PORTLAND CEMENT CONCRETE WELL MIXED WITH CLEAN WATER IN PROPORTION 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per yard cube	48	0
Do.	do.	in columns	„ „	53	0
Do.	do.	in beams	„ „	53	0
Do.	do.	in floor slabs 4 in. thick	per yard super	5	7
Do.	do.	in floor slabs 6 in. thick	„ „	8	4
Do.	do.	in floor slabs 9 in. thick	„ „	12	1
Do.	do.	in walls 6 in. thick	„ „	8	7

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

STEEL REINFORCEMENT, INCLUDING CUTTING, BENDING AND PUTTING INTO POSITION AND SECURING WITH STOUT BINDING WIRE—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	24	0
„ 7/16 in. to ½ in.	„	23	0
„ ⅝ in. to 2⅞ in.	„	22	0

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.*

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.*

SHUTTERING—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	57	6
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	53	6
Do. do. in small quantities	per ft. super	0	9½
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last, in narrow widths	„ „	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	„ „	1	1
Do. do. as last, in narrow widths	„ „	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	„ „	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/8½ per hour; Labourers on building works, 1/3½; Operators on concrete mixers and hoists, 1/4½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

PROSPECTIVE NEW CONCRETE WORK.

ADWICK-LE-STREET. — *Houses.* — The U.D.C. has applied to the M.H. for sanction to erect 300 houses.

ALDERSHOT.—*Houses.*—The T.C. has applied to the M.H. for permission to erect 50 houses by direct labour, estimated to cost about £500 each.

AUGHNACHRY.—*Reservoir.*—The Clogher R.D.C. has applied for sanction to construct a 10,000-gallon reservoir.

BARNES (LONDON).—*Houses.* — The L.C.C. proposes to purchase 54 acres of land for housing purposes.

BEDLINGTON.—*Bridge.*—The Blyth and Bedlington District Councils propose reconstructing the bridge at Bedlington in reinforced concrete.

BLACKHEATH (LONDON).—*Houses.*—The Greenwich B.C. proposes to build 400 houses at Blackheath.

BLACKPOOL.—*Defence Works.*—The Corporation has applied for sanction to borrow £182,226 for sea defence works and extensions to the promenade.

BLYTH.—*Promenade.*—The T.C. proposes to construct a concrete promenade.

BOURNEMOUTH. — *Houses.* — The Corporation proposes to build 92 houses.

BURNLEY.—*Houses.*—The T.C. proposes to erect 56 houses on the Palace House estate.

CAERPHILLY. — *Houses.* — The U.D.C. has applied to the M.H. for permission to build 300 houses.

CHAPEL-EN-LE-FRITH. — *Houses.*—The Parish Council recommends the erection of 100 houses.

CRAYFORD.—*Bridge.*—The U.D.C. is considering the question of erecting a bridge to span the road at Maiden Lane.

DONCASTER.—*Concrete Houses.*—The Corporation Housing Committee proposes to erect 400 concrete houses.

EASTBOURNE.—*Concrete Houses.*—The Corporation is considering a scheme for the erection of 200 concrete houses.

EDMONTON (LONDON).—*Houses.*—The U.D.C. proposes to erect 82 houses by direct labour.

EDMONTON (LONDON).—*Sewage Works.* —The U.D.C. has applied to the M.H. for a grant towards the improvements at the sewage works, estimated to cost £140,000.

EVESHAM.—*Bridge.*—The Worcs. C.C. proposes to erect a reinforced concrete bridge over the Avon at Evesham, at an estimated cost of £40,500.

FALKIRK.—*Houses.*—The T.C. has under consideration the construction of 282 houses.

GODSTONE.—*Houses.*—The R.D.C. has applied for sanction to erect 200 houses.

HAMMERSMITH (LONDON).—*Houses.*—The B.C. proposes to erect 115 houses.

HEANOR.—*Houses.*—The U.D.C. has made application to the M.H. for sanction to erect 115 houses.

KENSINGTON (LONDON).— *Houses.* — The B.C. is considering the question of erecting 160 houses.

LEADGATE.—*Sewage Works.* — The U.D.C. has applied to the M.H. for permission to borrow £11,371 for the construction of sewage disposal works.

LOWESTOFT.—*Groyne.*—The T.C. has applied for sanction for a loan of £10,000 for the construction of a groyne.

MAIDSTONE.—*Concrete Houses.* — The Council has applied for sanction to borrow £15,780 for the construction of 44 concrete houses.

MANSFIELD.—*Concrete Houses.* — The T.C. is considering a scheme for the erection of concrete houses.

NORWICH.—*Houses.*—The T.C. proposes to erect 100 houses by direct labour.

READING.—*Bridges.*—The T.C. proposes to reconstruct three bridges in reinforced concrete, at an estimated total of £57,000.

SALISBURY.—*Houses.*—The Corporation has applied for sanction to borrow money in connection with the construction of 30 houses.

SANDGATE.—*Groynes.*—The U.D.C. has a scheme in hand for the construction of two groynes near Battery Point.

SELBY.—*Road.*—The U.D.C. has a scheme on hand for the construction of a road between Gowthorpe Street and Flaxley Road.

SHIPLEY.—*Houses.*—The U.D.C. has a scheme on hand for the erection of 180 houses.

SOUTHAMPTON.—*Jetties.*—The Southern Railway Co. has received the sanction of Parliament for the reclamation scheme between Town Pier and Southampton West Station. Two reinforced concrete jetties, each 1,000 ft. long by 260 ft. wide, are to be constructed on the new river frontage.

Southport.—*Houses.*—The Corporation proposes to erect 100 houses.

South Shields.—*Houses.*—The Corporation has a scheme in hand for the erection of 480 houses.

Stapleford.—*Houses.*—The R.D.C. is seeking permission to build 100 houses.

Thetford.—*Concrete Wall.*—The District Council proposes to construct a concrete wall along the Ouse, at a cost of £1,000.

Tredworth.—*Houses.*—The Gloucester C.C. proposes to erect 94 houses at Tredworth.

Twickenham.—*Houses.*—The U.D.C. has applied to the M.H. for permission to erect 100 houses.

Warrington.—*Bridge.*—The T.C. is considering a scheme for the construction of a concrete bridge to replace Buttermilk Bridge

Warrington.—*Houses.*—The T.C. is considering the purchase of 101 acres of land for the construction of 1,100 houses.

West Hartlepool.—*Houses.*—The T.C. has applied to the M.H. for sanction to erect 161 houses.

Whitehaven.—*Road.*—The Corporation has applied for sanction to borrow £13,276 for the construction of a road from Ginus to the High Road.

TENDERS ACCEPTED.

Altofts.—*Footpaths.*—The U.D.C. has accepted the tender of Mr. T. Waddington, Wakefield, for relaying 240 yards of concrete footpath.

Birmingham.—*Concrete Houses.*—The Corporation Public Works Committee has accepted tenders for the construction of concrete houses.

Bristol.—*Concrete Houses.*—The T.C. has accepted the tender of Mr. J. Knox for the construction of 270 concrete houses.

Bury.—*Concrete Pipes.*—The T.C. has accepted the tender of Mr. J. G. V. Freeman, Hollinwood, for the construction of concrete pipes.

Chapel-en-le-Frith.—*Sewage Works.*—The R.D.C. has accepted the tender of Messrs. G. D. Hayes and Son, Stockport, at £6,503, for the construction of sewage disposal works.

Chelmsford.—*Wall.*—The T.C. has accepted the tender of Mr. W. A. Claydon, Ulting, at £972, for the construction of a reinforced concrete boundary wall.

Colne.—*Sewer.*—The T.C. has accepted the tender of Messrs. J. Byrom, Ltd., Bury, for the construction of a concrete sewer.

Durham.—*Wall.*—The T.C. has accepted the tender of Messrs. Holloway and Co., at £5,713 5*s.* 8*d.*, for the construction of a concrete wall.

Exeter.—*Warehouse.*—Messrs. Rowe Bros. have accepted the tender of Messrs. R. F. Yeo and Sons., Ltd., Torquay, at £21,734 16*s.* 11*d.*, for the construction of a reinforced concrete warehouse.

Geddington.—*Bridge.*—The R.D.C. has accepted the tender of Mr. G. F. Hartigan, Northampton, at £2,856 6*s.* 6*d.*, for reconstructing Braunston Bridge in reinforced concrete.

Haslemere (Surrey).—*Reservoir.*—The U.D.C. has accepted the tender of Messrs. J. A. Ewart, Ltd., at £650, for the construction of a reinforced concrete reservoir with a capacity of 54,000 gallons.

Hastings.—*Grand Stand.*—The T.C. has accepted the tender of Messrs. L. J. Speight, Ltd., at £19,980 1*s.*, for the construction of a reinforced concrete grand stand.

Honiton.—*Bridge.*—The T.C. has accepted the tender of Messrs. Fothergill Bros., Exeter, at £1,250 10*s.* 7*d.*, for taking down the existing stone bridge at Honiton and erecting a concrete bridge on the site.

India.—*Formwork.*—The tender of Messrs. Christmas and Walters, Ltd., of 300, Caxton House, Westminster, S.W.1, for 38,000 sq. ft. of "Blaw" steel forms, has been accepted by the High Commissioner of India.

Lanchester.—*Concrete Kerbing.*—The R.D.C. has recommended for acceptance the tender of Messrs. Bolckow, Vaughan and Co., Middlesbrough, for the supply of 5,460 lineal yards of concrete kerbing at 4*s.* 6*d.* per lineal yard.

Martley.—*Bridge.*—The R.D.C. has accepted the tender of the Reinforced Concrete Co., at £2,454, for the construction of a concrete bridge at Suckley.

Mobberley.—*Sewage Works.* — The Bucklow R.D.C. has accepted the tender of Messrs. G. D. Hayes and Son., Stockport, at £1,521 14*s.* 3*d.*, for the construction of sewage disposal works.

Thurnscoe.—*Sewage Works.* — The U.D.C. has accepted the tender of the Provincial Construction Co., Ltd., Sunderland, at £25,000, for the construction of sewage works.

Worthing.—*Pier Pavilion.*—The Corporation has recommended for acceptance the tenders of Messrs. F. Sandell and Sons, Worthing, at £29,855, for the construction of a concrete pier pavilion, and £19,125, for the construction of a concrete band enclosure.

York.—*Houses.*—The T.C. has recommended for acceptance the tender of Messrs. F. Shepherd and Son., York, at £139,297 10*s.*, for the erection of 300 steel-framed concrete houses.

BUILDING AND DECORATIVE EXHIBITION, LEICESTER.

Concrete was well represented at the Building and Decorative Exhibition held at the Junior Training Halls, Leicester, from October 5 to 25.

At the stand of the Concrete Utilities Bureau, a variety of uses of concrete was illustrated, prominent among which were the applications of the material to the building industry. These included three examples of walling—the ordinary cavity wall, whose inner leaf was composed of breeze blocks, a section of Messrs. Winget's new pier-and-panel method of wall-building and rockface blocks. Concrete roofing was represented by interlocking tiles in a variety of colours, supplied by the Everlasting Tile Company, and Broseley pattern tiles made by the Bedfordshire Tile Company of Leighton Buzzard. Another form of concrete roofing consisted of russet brown " Poilite " straight cover slating supplied by Messrs. Bell's Poilite & Everite Company. These slates are composed of cement-asbestos material, and are thin but very tough. Examples of the " Big Six " corrugated asbestos roofing made by the same firm were also shown ; this form of roofing has been used to cover the stand at the ground of the Leicester Association Football Club.

Some excellent examples of cast stone were among the exhibits. One of these was a window and door erected in blocks made to represent Ham stone in different shades. This is one of the specialities of the Wharf Lane Concrete Company of Ilminster, who also lent other products all carried out on the same method. Other examples of cast stone were supplied by the Croft Granite, Brick and Concrete Company. Among these were two ornamental urns with pedestals, two lamp standards, a pergola and a slab for supporting a gas stove. Other examples of the products of this firm were a kerb and channel, paving slabs and an 18-in. sewer pipe. One of the uses of concrete in the garden was illustrated by a garden frame supplied by Messrs. Evans Bros., of Riddings, Alfreton. These frames are pre-cast, the four pieces of which they are composed being bolted together ; they are so constructed as to render extension possible.

The decorative possibilities of concrete were well exemplified by a set of panels which had been treated by the " scrubbing " method. By this method, which has already been described in this journal, specially selected aggregates are employed and after the concrete has set the surface film of cement is scrubbed off with a stiff brush and clean water and the aggregate revealed. This method opens up great possibilities for the use of concrete for decorative purposes. On Messrs. Winget's stand concrete machinery of various kinds was exhibited, including a new " chain spade " mixer. Messrs. Novocretes, Limited, showed examples of their lightweight concrete. One interesting exhibit consisted of a tile on which a miniature water pond had been standing for a week without sign of permeation. The possibilities of this material were shown by two slabs which had taken on a high polish. Other firms exhibiting concrete products or machinery were the Alexandra Paving Stone Co., Nuneaton ; Concrete Specialties Co., New Queniborough ; Messrs. Henry Boot ; Triangular Construction Co. ; Conbloc Co., East Grinstead ; Messrs. Goodwin Barsby, Sheffield ; Corolite Construction Co., London ; F. Parker, Leicester, and the Yorkshire Hennebique Contracting Co., Leeds.

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NINETEENTH YEAR OF PUBLICATION

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By appointment to
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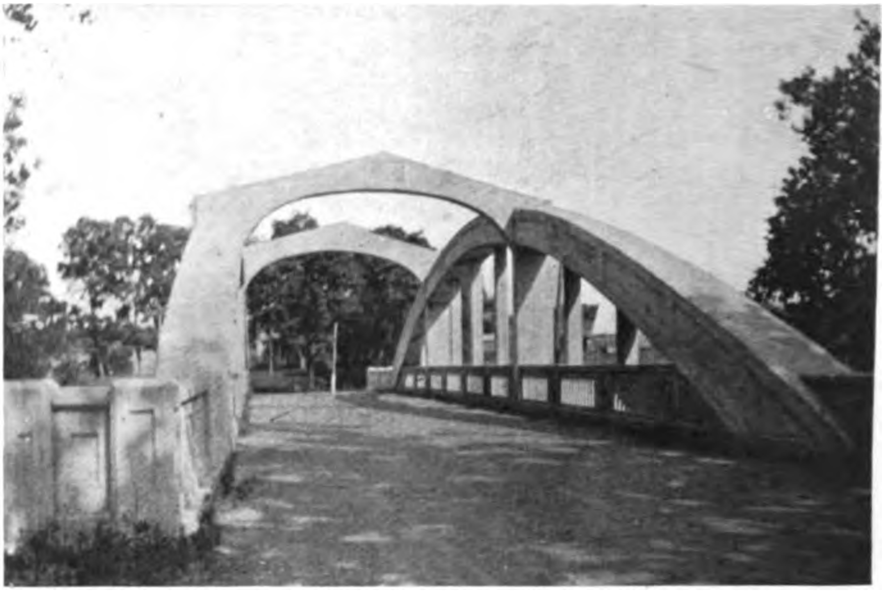


REINFORCED CONCRETE BRIDGE IN AN AMERICAN PARK.

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XIX. No. 12. LONDON, DECEMBER, 1924.

EDITORIAL NOTES.

PROPRIETORS' NOTICE: CHANGE OF ADDRESS.

We should be glad if our subscribers and other friends would note that the address of Concrete Publications, Limited, has been changed from No. 35, Great St. Helens, London, E.C.3, to No. 20, Dartmouth Street, Westminster, S.W.1, and that our new telephone number is Victoria 4581. We have for some time thought of taking accommodation in Westminster so as to be nearer to the engineers in that district, and the change is now imperative on account of the development of the book publishing side of the business making more accommodation necessary. The Publishing Office remains at No. 4 Catherine Street, Aldwych, W.C.2.

STRUCTURAL STEELWORK REINFORCED WITH CONCRETE.

As pointed out by Mr. Ewart S. Andrews in our issues for September, 1923, and January, 1924, a certain amount of experimental work to ascertain the strength added to structural steel by encasing it in concrete has already been carried out in the United States. By the generosity of Messrs. Redpath, Brown & Co., Ltd., in presenting a suitable testing machine to the National Physical Laboratory, these investigations have been carried a considerable step farther by Mr. J. Mitchell Moncrieff and Mr. J. R. Sharman, the results of whose tests on this machine are given in this issue. It will be seen that specimen 4 in. by 3 in. joists 193 in. long gave breaking strengths of 5·18 tons and 4 tons respectively when tested uncased with concrete, and that when cased in concrete to approximately 8 in. by 8 in. these loads were increased to 48 tons and 55·2 tons. Similarly, uncased steel stanchions 5 in. by 4½ in. had a breaking strength of 12·7 tons, and when cased in concrete to 8 in. by 7½ in. the breaking strength was increased to 46·1 tons and 40·4 tons respectively in the specimens tested. As Dr. Faber points out in an introduction to these tests: "The great discrepancy between the strength of the cased and uncased specimens (the difference in the case of the 4 in. by 3 in. joist is roughly 50 tons cased compared with 5 tons uncased) is one which no regulations allow advantage to be taken of, and if the tests serve no other purpose they do constitute a very serious challenge as to whether some recognition of this great increase in strength ought not to be made on a conservative basis in building regulations. . . . There are undoubtedly cases where it would be perfectly legitimate to take advantage in the design of this increased strength, and there is no reason why, with suitable safeguards, building regulations should not allow of this strength being taken into account in design. The calculations required are perfectly simple and on an entirely rational basis, which check excellently against actual tests." Our thanks are due to Messrs. Redpath Brown & Co., Ltd., for permission to publish the results of these valuable tests.

NEW METHODS OF HOUSE BUILDING.

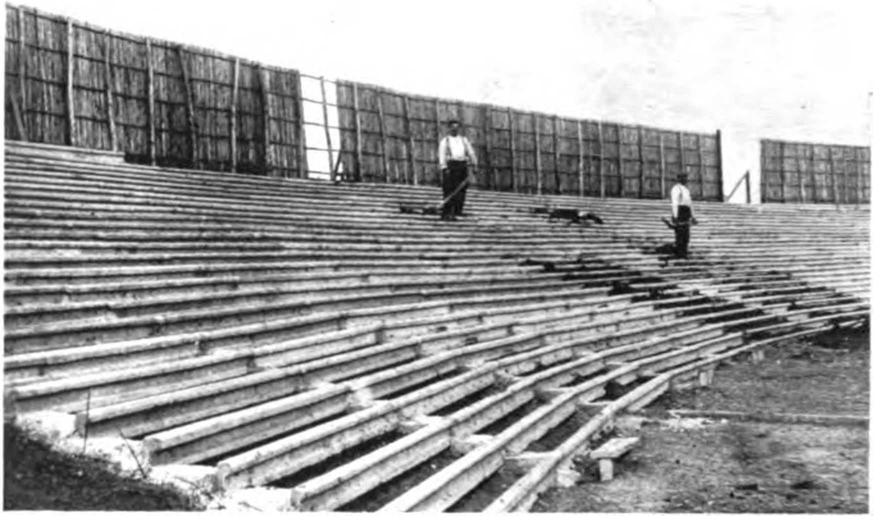
THE Committee appointed by the Ministry of Health of the late Government to enquire and report on new methods and materials for the erection of working-class houses seems to have taken its terms of reference literally, and has first reported on the newest material advocated for this purpose. This, we gather, has been done at the special request of the Minister, who desired to have an opinion on the timber-and-steel houses in which Lord Weir, the Duke of Atholl, and others are interested. The Committee does not commit itself either in favour of or against this type of construction, contenting itself with an expression of opinion that " this type of house is deserving of encouragement . . . where for any reason more permanent types of buildings cannot quickly be provided." After a thorough examination of the methods of construction and of specimen steel houses the Committee has not been able to determine whether such buildings would be any cheaper than brick or concrete, but points out that owing to the fact that their life cannot be put at longer than forty years, and that maintenance charges would be greater than in the case of brick or concrete, it is necessary that steel houses should be cheaper in first cost if they are to compare on an equal financial basis with brick or concrete.

The opinion has been expressed in some quarters lately that in the present emergency the cheapest type of temporary house should be built in large numbers as an expedient to overcome the financial difficulties of building an adequate number of permanent houses and the shortage of bricklayers and other skilled building labour, and in their desire to build cheaply the exponents of this policy are advocating such materials as corrugated iron. While fully agreeing that if one cannot afford the best one must be content with an article of inferior quality or something in the nature of a makeshift, we think there are other considerations to be taken into account in the provision of houses with State aid. The fact has to be faced that at present prices houses cannot be built to let at a rent the working-classes can afford to pay, and that without a subsidy private enterprise cannot operate. The onus of financing housing schemes must therefore necessarily fall upon the Government and the local authorities, which are on an entirely different footing from private persons so far as the raising of money is concerned. A private person with insufficient means to purchase what he requires must generally be content with something less costly, but a local authority or a Government can borrow money for a long period. Experience since the war has shown that the local authorities have been forced to build themselves, and there is nothing to suggest that this will not be the case in the future. That being so, there can hardly be any economical advantage in local authorities building temporary houses which will be unfit for habitation within fifteen or twenty years (the life expected of the temporary house), or which will need large expenditure for repairs. It seems to us it would be a far better business proposition for the authorities to obtain loans for a longer period and build houses which will still stand and have a value after the loan has been repaid. If local authorities are to be landlords of large numbers of working-class houses such property should be put on the same footing as other municipal undertakings. We have never yet heard it suggested that water supply or other works, the cost of which is recouped from the rates in the same way as houses, should be built of cheap and temporary materials in order to keep the initial cost at a minimum. It cannot be a sound policy to look upon the present housing shortage as an evil to be remedied by the erection of temporary accommodation. The difference in cost between a makeshift house and a permanent one, each with the same standard of fittings and comfort inside, can, in our opinion, never be sufficiently lower to warrant the view that the shortage can be overcome by spending money on property with such a short life that it will never become remunerative, and which, moreover, will leave us with the housing problem just as acute when they have become unfit for habitation within fifteen years' time.

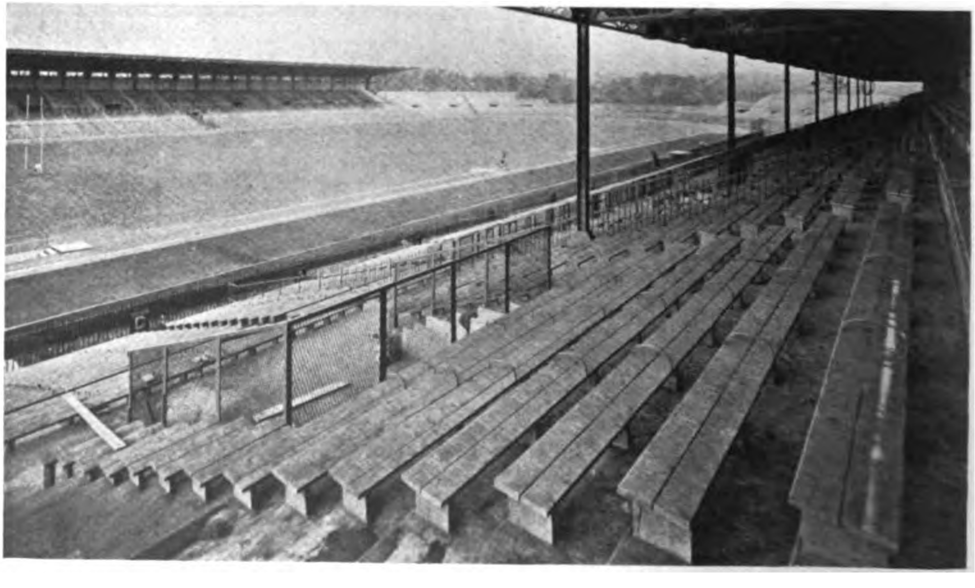
We do not agree with all the ideals of housing reformers—the effort to attain which has probably been one of the greatest factors in the failure of previous housing schemes—but at the same time a realisation that the " homes for heroes " were to be built of corrugated iron and similar materials could hardly be expected to allay social unrest or make for a contented population. The middle course is generally the wisest, and it will undoubtedly be found that the solution of the problem will lie in the erection of substantial and durable houses which will provide dwelling accommodation over a long period of years. Concrete has already been used, and is now being used, so extensively for such permanent houses that failing facilities for building in brick at a competitive cost, of which there seems no probability in the near future, we have no doubt whatever it will be the material chiefly used for the majority of the new houses. A factor in the situation which is now being realised, and which will become of more importance as more concrete houses are built, is that there is a large and growing body of men familiar with the use of concrete for small house construction who will, as time goes on, lessen the power which the bricklayer now enjoys of dictating to the community the extent of its housing accommodation.

QUICK-HARDENING PORTLAND CEMENT.

SOME important tests are now being undertaken by Professor Dixon at the City and Guilds Engineering College, South Kensington, on a new quick-hardening Portland cement which is being put on the market by the Cement Marketing Company, Ltd. Tests are being made on beams and cubes made with ordinary Portland cement and the new quick-hardening Portland cement, all the test pieces being composed of a 1 : 2 : 4 mixture made under exactly the same conditions, the only difference being in the cement. The beams are 16 ft. long by 10½ in. deep, by 6 in. wide, resting on knife-edge supports 6 in. from each end and the load applied at points 2 ft. 6 in. from the centre in each direction. So far tests have been made at ages of approximately 2 days, 4 days, and 7 days, when the beams cracked under the following loads: Age 56 hours—Portland cement 4,000 lbs., quick-hardening cement 14,000 lbs.; 100 hours—Portland cement 7,000 lbs., quick-hardening cement 1,900 lbs.; 7 days—Portland cement 9,260 lbs., quick-hardening cement 21,000 lbs. Crushing tests on 6-in. cubes gave the following results: Age 56 hours—Portland cement 700 lbs. per sq. in., quick-hardening cement 2,450 lbs.; 100 hours—Portland cement 1,200 lbs., quick-hardening cement 4,000 lbs.; 7 days—Portland cement 1,250 lbs., quick-hardening cement 5,100 lbs. The quick-hardening cement is a true Portland cement. We hope to give further particulars of these tests and of the 28-day tests in our next issue.



TERRACING FOR STANDING ACCOMMODATION.



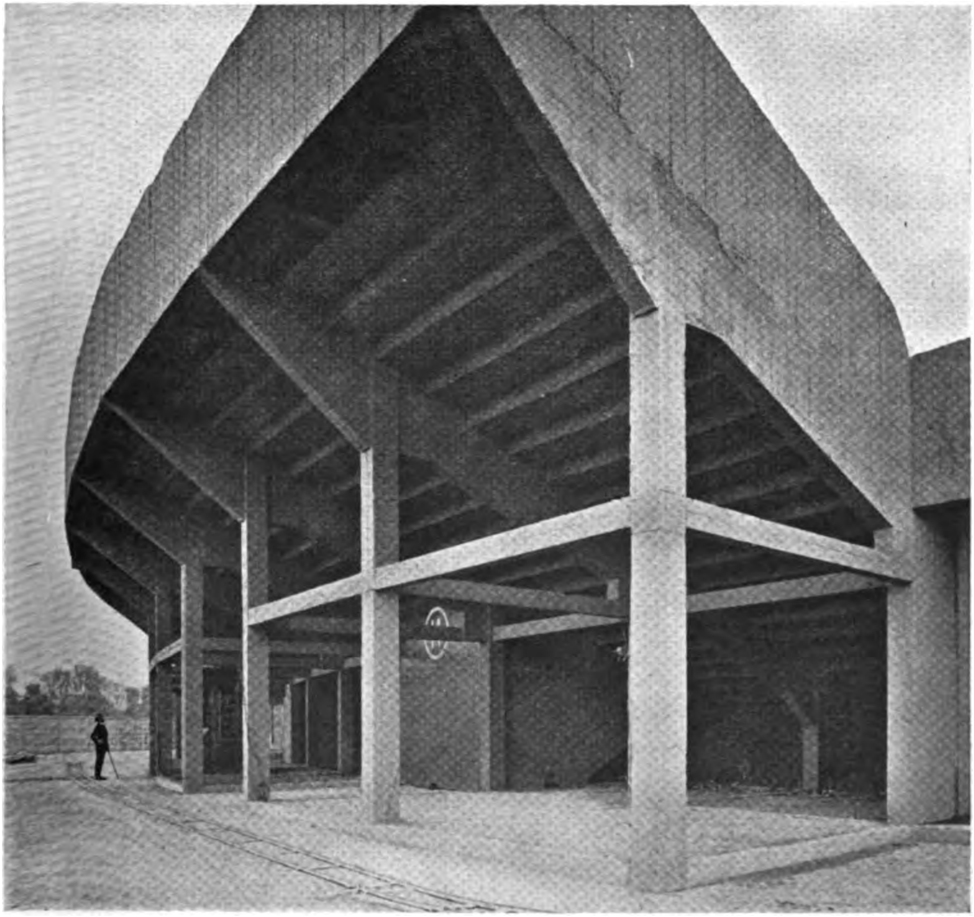
TERRACING FOR SEATS UNDER COVER.

THE STADIUM AT COLOMBES. (*See p.* 749.)

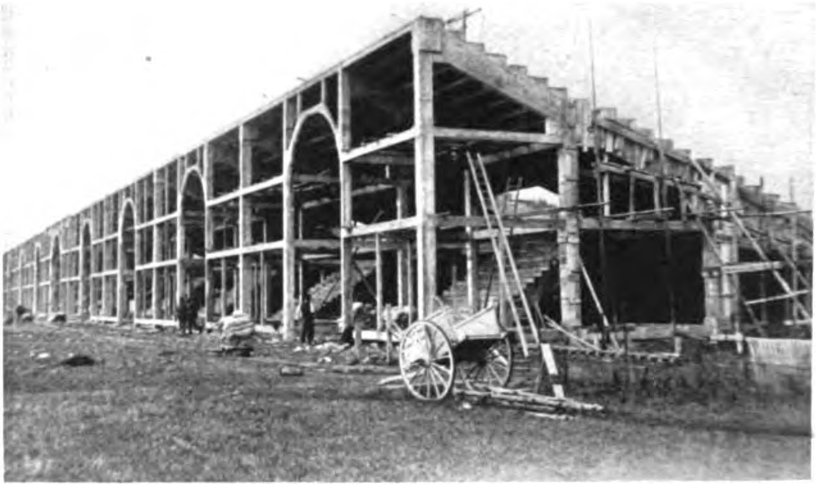
THE STADIUM AT COLOMBES.

In this issue we give some illustrations of the stadium specially built at Colombes, near Paris, for the Olympic Games this year. With the exception of the roofing over the seats the whole of the construction is of reinforced concrete. The stadium accommodates a total of 60,000 persons, 40,000 standing and 20,000 seated, the seating accommodation being situated in the centre on each side and the standing space at the ends.

The track is approximately 550 yds. long, and encloses a grass-covered area for football and other sports. The terracing for standing spectators is formed of reinforced concrete risers resting on reinforced concrete girders spaced 11 ft. 6 in. apart on an earth embankment for the lower part (up to a height of 7 ft. 6 in.), and above that on a reinforced concrete framework. Each step has a rise of 9½ in. and a tread of 26 in., providing space for two rows of spectators. Seats are



View Under Terracing.



The Stadium at Colombes during Construction.

provided on each side of the stadium for a length of 476 ft. and a depth of 87 ft., the lower part on an earth embankment and the upper part on a reinforced concrete framework similar to the terracing for standing spectators. The treads of the stepping on which the seats are placed are 26 in., the rise varying from 8¾ in. at the lower part to 10¼ in. at the upper part. The seats are entirely of concrete.

The space under one of the seating areas is used for cloakrooms, halls, restaurant, etc., the whole of this construction being in reinforced concrete, as also are the stairs leading up to the seats.

GRAPHICAL METHOD OF SOLVING CONTINUOUS BEAMS.

By F. W. DAVEY, A.M.Inst.C.E.

THE solution of the problem of continuous beams is of special importance in reinforced concrete design, and the adaptation of Professor Claxton Fidler's method of "characteristic points" may be of interest to engineers.

The method as explained in Professor Fidler's paper in the Proceedings of the Institution of Civil Engineers (Volume LXXIV) is simple and practicable, and also lends itself to a rapid estimation of the probable effects of the sinking of one or more supports. It has one serious limitation, however; except for a brief note at the end, it confines itself to the case of a continuous beam of constant moment of inertia. This is only rarely the case in practice, for (*a*) should the spans be unequal, the reinforcement of the various spans is almost certain to be unequal, and (*b*) the moment of inertia at columns is always different from that in mid span owing to haunches and negative steel. From an examination of many cases in practice the writer has found that the second point introduces errors of only 2 or 3 per cent., but that the first is too important to neglect. By a slight modification, Professor Fidler's method can be adapted to this condition. As it possibly is not known to a number of readers a brief résumé of it, as modified, may be valuable.

First take the case where the supports are on the same level. Let *BCD* (*Fig.* 1) be a portion of a continuous beam over three supports, *B*, *C*, and *D* and let *TCT'* be the tangent at support *C*.

Let the curves *BeC*, *CfD* (*Fig.* 2) be the bending moment diagrams of spans *BC* and *CD* considered as free spans; and *b'c'd'* a new base line such that the shaded diagram is the true bending moment diagram (at present undetermined) for the continuous beam.

It is proved in most books on applied mechanics that

$BT =$ sum of moments of shaded diagram $Bb'c'Ce$ about $C \div EI_2$ where I_2 is the moment of inertia (assumed constant) of span BC.

and $DT' =$ sum of moments of shaded diagram $Cc'd'Df$ about $C \div EI_3$.

Now, if each span is divided into three equal parts by vertical lines *uk*, *ul*, etc., and "characteristic points" *k*, *l*, *m*, *n*, plotted on them such that the height vl for instance = moment of curved area BeC about $C \div \frac{L_2^2}{2}$, it is a matter of simple geometry to show that

$$ll' \times \frac{L_2^2}{2} = \text{moment of shaded diagram } bb'c'ce \text{ about } C$$

and therefore $= BT \times E.I_2$

and similarly $mm' \times \frac{L_3^2}{2} = DT' \times E.I_3$

Now clearly
$$\frac{BT}{L_2} = \frac{DT'}{L_3}$$

$$\frac{ll' \times L_2^2}{2E.I_2 \times L_2} = \frac{mm' \times L_3^2}{2E.I_3 \times L_3}$$

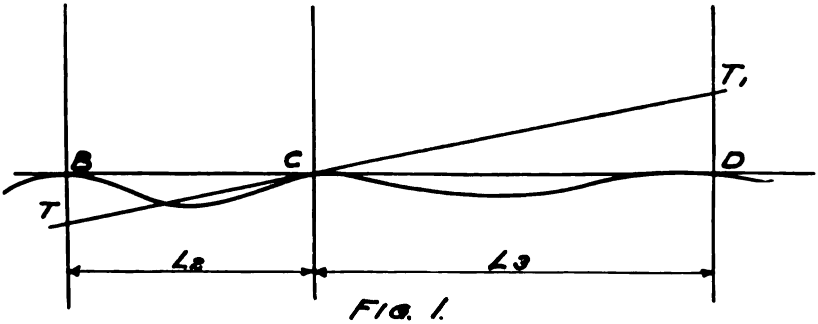


FIG. 1.

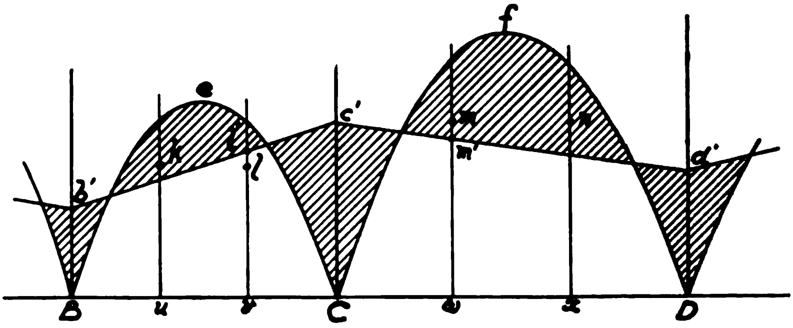


FIG. 2.

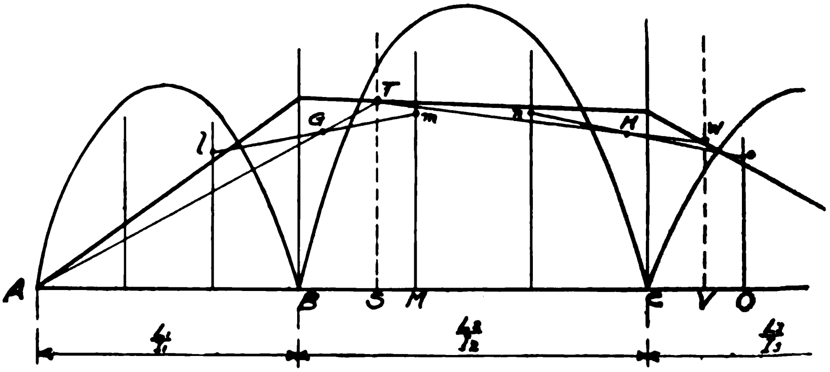


FIG. 3.

GRAPHICAL METHOD OF SOLVING CONTINUOUS BEAMS.

or $$ll' \times \frac{L_2}{I_2} = mm' \times \frac{L_3}{I_3}$$

Therefore, having drawn the free bending moment *BeC*, *CfD*, etc., if we can plot the new base line *b'c'd'* such that

$$ll' \times \frac{L_2}{I_2} = mm' \times \frac{L_3}{I_3} \text{ and so on all the way along,}$$

we shall have the true bending moment diagram for the beam.

The best way of doing so is first of all to plot the free bending moment diagrams on spans proportional to length of span ÷ moment of inertia at centre of span, instead of using true spans. Then calculate and plot the "characteristic points." For uniform load or for the common 3 point load the height vl will be two-thirds the maximum free moment of the span, and for any symmetrically loaded span the points will be at the same height from the base.

Starting now from the second span from the left, divide *BM* (*Fig.* 3) in *S* such that $\frac{BS}{MS} = \frac{BC}{AL}$ and draw perpendicular *ST*.

Join *lm* and divide in *G* such that $\frac{lG}{mG} = \frac{BC}{AB}$.

(*Note.*—The best way of making these divisions is to scale with a decimal scale and use a slide rule. Do not aim after excessive accuracy.)

Through *G* draw *AGT* cutting *ST* in *T*. Then *T* is a point on the new base line.

In the same way, proceed to the next span, dividing *CO* in *V* so that $\frac{VO}{VC} = \frac{SN}{SC} \times \frac{BC}{CD}$ and draw perpendicular *VW*.

Join *no* and divide in *H* so that $\frac{nH}{oH} = \frac{CD}{BC}$. Draw *THW* cutting *VW* in *W*. The *W* is a point in the new base line.

Thus work right along the beam, getting one point in each span on the new base line. In the case of the last span the base line must reach zero at the last support (if there is no fixation), thus fixing the base line of this span. The complete base line may now be drawn by starting with this last span.

It is very useful in practice to be able to make allowance for the live load being in its worst position, which for negative moment at supports occurs when two adjacent spans are loaded flanked by two unloaded spans; while for positive moments in mid span it occurs when alternate spans are loaded.

The following approximate allowances are sufficiently accurate for ordinary cases where $\frac{L}{I}$ is fairly constant :—

Increase in negative moment—¼ of free B.M. due to live load (take mean of each side of pier considered).

Increase in positive moment—

(*a*) Many spans — ⅓ of free B.M. due to Live Load.
(*b*) End span — ⅙ ,, ,, ,, ,, ,,
(*c*) Centre of three spans — ·4 ,, ,, ,, ,, ,,

Finally, to estimate the probable effect of a sinking of S inches in the support, work out the value of $\frac{S'' \times 2EI}{L} = X$, say, all in inch and lbs. units.

Then increase in positive moment (in inch lbs.) $= \cdot 8X$ for uniform load
$= \cdot 9X$,, 3 point load

and increase in negative moment $= \cdot 4X$

In drawing the parabolic curves of the complete bending moment diagram to determine points of inflexion, i.e of zero moment (which are needed in finding shears and reactions at supports), the writer uses the adjustable parabola made by Harlings. This diagram should be a natural scale for spans.

BOOK REVIEWS.

Constructional Steelwork. By H. Atkin.
London : Chapman & Hall, Ltd. Pp. 212 Demy 8vo. Price 9s. 6d.

THIS book deals with the fabrication side of structural steelwork, and as many students and draughtsmen have not much opportunity of obtaining information on this very important branch of the subject, the book may be regarded as a welcome addition to the available literature.

The author, who clearly writes from first-hand knowledge, describes first the general considerations and the equipment of a structural steel workshop. The next chapter deals with stock unloading and straightening ; this is followed by chapters on planing machines and section-cutting machines in which the leading types of machines are described. We then pass to chapters upon the important questions of setting-out and templet systems, and the author strongly advocates metal templeting as more economical than wood templeting. The next two chapters deal with marking-off and round work, and are followed by chapters upon punching and shearing machines, rivets and riveting and compressed air plant. These are followed by a short chapter dealing with smithing and presswork, after which we have chapters upon grinding and assembling work. The final chapter deals with "the human element," and explains the conditions of work usually observed in girder yards.

In reading the book we were specially struck by two things. The first is that we did not find in the book any reference to the cutting of structural sections by means of the blow pipe ; the second is a curious simplicity of language which occasionally rises to humour, presumably unconscious, of which the following gem is a delightful example : "The presence on the market of cheap foreign steel has to be taken into consideration, and whilst such steel might not pass the tests of English railway companies and other users of steelwork who consider the safety factor, its sphere of usefulness is great."

E. S. A.

L.C.C. Regulations relating to Reinforced Concrete and Steel Frame Buildings. By Ewart S. Andrews.
London : B. T. Batsford, Ltd. Pp. 83. Price 3s. 6d. net.

THIS is the third edition of an almost invaluable book to all concerned with the erection of large modern buildings. It contains the full text of the London County Council Regulations relating to Reinforced Concrete (London Building Act, 1909, Amendment) and Steel Frame Buildings (L.C.C. General Powers Act, 1909), with explanatory notes and diagrams for the assistance of engineers and architects in the calculations required by the Regulations, particularly in those cases in which the calculations differ from the usual practice or the meaning of the Regulation is not evident.

STEEL REINFORCED WITH CONCRETE.

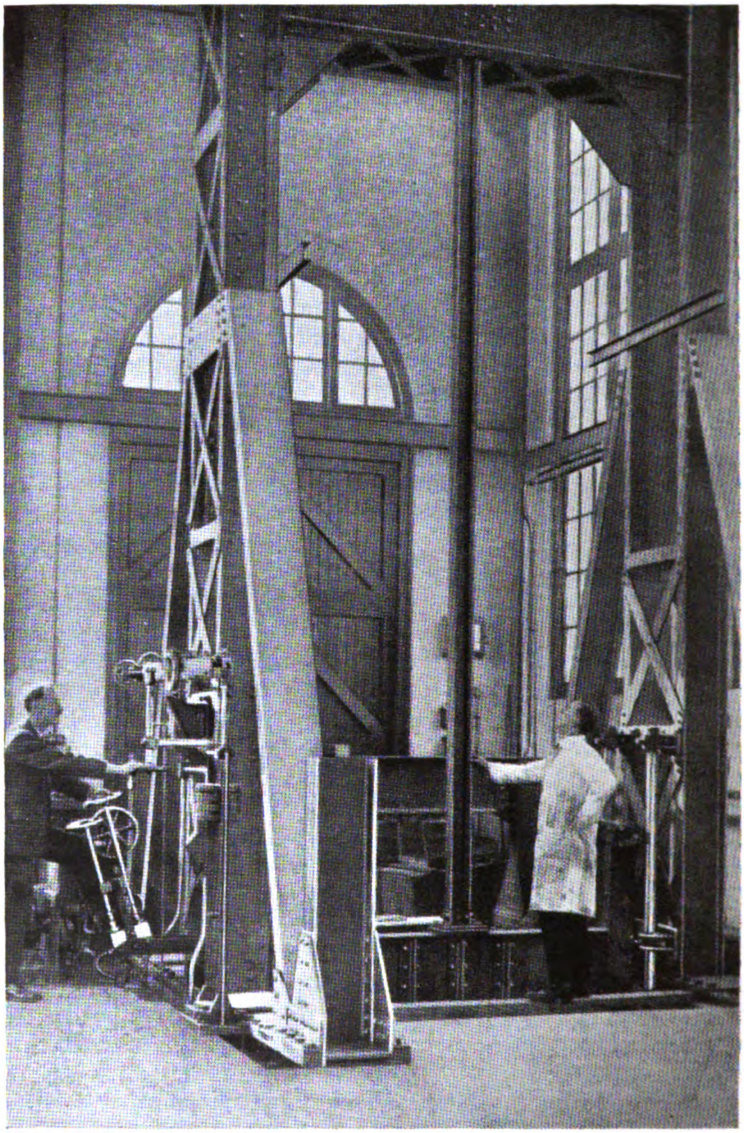
By OSCAR FABER, O.B.E., D.Sc., M.Inst.C.E.

By the courtesy of Messrs. Redpath, Brown & Co., Ltd., the writer was present at the National Physical Laboratory at Teddington to witness some interesting tests on steel joists cased in concrete and tested in compression as stanchions, as well as tests on slabs composed of steel joists filled in with concrete. Messrs. Redpath, Brown have collected the principal results of these experiments in the form of a small pamphlet which is given later.

Referring to the first series, which are column tests, it will be seen that the 4 in. by 3 in. joists at a length of 193 in. gave a breaking strength of 5·18 tons in one case and 4 tons in the other. When they were cased in concrete, roughly speaking 8 in. by 8 in., these loads were increased to 48 tons and 55·2 tons. Similarly, stanchions of 5 in. by 4½ in. steel joists gave 12·7 tons tested alone, and 46·1 and 40·4 tons respectively when cased in concrete 8 in. by 7½ in.

The chief point of interest in these tests is perhaps more in relation to building regulations than to theoretical knowledge. The breaking loads on the steel stanchions agree excellently with the results of the ordinary buckling formula, while the strength of the cased joists agree quite well with the breaking strength of reinforced concrete columns of that size, giving a stress in the neighbourhood of 1,600 lbs. per sq. in. of concrete, which no doubt represents approximately the average strength of the concrete used, which it may be said in passing was made with less than the skill that one could reasonably expect on first-class work. There is therefore nothing very startling from a theoretical point of view. Nevertheless the great discrepancy between the strength of the cased and the uncased specimens (the difference in the case of the 4 in. by 3 in. joist is roughly 50 tons cased compared with 5 tons uncased) is one which no regulations allow advantage to be taken of, and if the tests serve no other purpose they do constitute a very serious challenge as to whether some recognition of this great increase in strength ought not to be made on a conservative basis in building regulations. A reasonable basis for design would perhaps be to allow such composite sections to be calculated as reinforced concrete after perhaps insisting that 2 in. cover of concrete on the outside shall not be taken into account in calculating the strength, but reserved for fire-resistance in such structures where fires are possible. The minimum of binding would no doubt have to be specified, as well as a minimum quality of concrete, but even with such safeguards there would be many cases where economy of construction and the avoidance of obstruction by unnecessarily large members would be avoided.

Coming now to the tests of floor slabs, it is interesting to note that, where the concrete extends considerably above the top of the joists, the test load, which is defined to be the load at which the proportionality between deflection and load ceases, is considerably increased, while the deflection of the construction at that test load is considerably reduced. Thus four 4 in. by 1¾ in. joists alone carried 7½ tons distributed, when the limit of proportionality was reached, and then at a deflection of 0·66 in. When filled with concrete between the joists and 3 in. above them, making a total depth of 7 in., the test load was increased to 14·3 tons, and the deflection reduced to 0·295 in. The increased strength results from an increase in the effective depth of the construction, the



MACHINE FOR TESTING STEEL JOISTS AND STANCHIONS ENCASED IN CONCRETE.

centre of compression now being raised, and the reduction in deflection from the consequent increase in the moment of inertia. Where the concrete only extends to the top flange of the joists no advantage from this cause would be expected, nor is any such advantage found from the tests.

It is perhaps only fair to observe that these slabs were not fire-proofed on the bottom flanges of the joists, and had they been the thickness of concrete and the weight of the floors would have been very great before much advantage was reaped from the presence of the concrete.

Nevertheless there are undoubtedly cases where it would be perfectly legitimate to take advantage in the design of this increased strength, and there is no apparent reason why, with suitable safeguards, building regulations should not allow of this strength being taken into account in design. The calculations required are perfectly simple and on an entirely rational basis, which check excellently against actual tests, such as those forming the subject matter of the pamphlet which follows.

INTRODUCTION.

In an introduction, Messrs. Redpath, Brown & Co., Ltd., state :

" In the course of our work we have often realised that the sizes of steel beams embedded in concrete could not be selected with accuracy, owing to the absence of definite data of the increase of strength due to the concrete ; and with a view to obtaining reliable records of the behaviour under test of concrete-encased steel beams, from which working formulæ could be constructed, we decided in 1914 to present to the National Physical Laboratory a machine suitable for experiments on horizontal and vertical specimens. We requested Mr. J. Mitchell Moncrieff, C.B.E., M.Inst.C.E., and Mr. J. R. Sharman, M.Inst.C.E., to advise us in regard to these tests. Mr. Sharman designed the machine in consultation with Mr. Moncrieff, and in collaboration with the Technical Staff of the National Physical Laboratory. The tests were arranged and carried out under the general supervision of these gentlemen.

" The war interfered with the making of the machine, and it was not until 1922–3 that a series of tests could be undertaken. The specimens tested consisted of a number of horizontal panels of steel beams of small section, with and without concrete filling, reproducing, in the case of those filled with concrete, as nearly as possible the conditions of a floor of similar construction as commonly used in buildings ; and also of a number of steel beam pillars, both plain and encased in concrete. The tests were made by the staff of the Laboratory with great care and accuracy, and we now submit a short report on the pillar tests, prepared by Mr. Mitchell Moncrieff, and on the floor slab tests, prepared by Mr. J. R. Sharman. These, we think, will be found interesting and conclusive, and from the results we hope to derive working formulæ capable of general application.

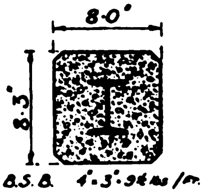
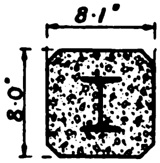
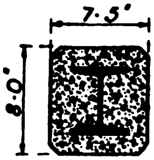
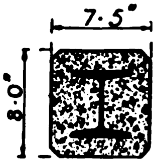
" The machine is now the property of the National Physical Laboratory, and, subject to arrangements being made with the Laboratory, is available for the testing of any suitable specimens which may be sent to them."

COLUMN TESTS.

In his report on the strength of compound columns of steel joist section encased in concrete, Mr. J. Mitchell Moncrieff says :

The object of the tests was to determine if possible to what extent the strength of an ordinary plain steel column may be increased by the addition of an outer casing of concrete such as might be applied for fireproofing purposes in the structure of a building.

The columns tested were eight in number. Four of these columns were formed of simple joist sections with caps of perfectly ordinary character, and without any concrete covering whatever.

COLUMN No.	SECTION	LENGTH	ULTIMATE STRENGTH.
1	BSB 4"·3"·9½ lbs PER FOOT RUN SECTL AREA - 2·795"" LEAST I·1·3	193 INCHES	5·18 TONS
2	BSB 4"·3"·9½ lbs PER FOOT RUN SECTL AREA - 2·795"" LEAST I·1·3	193 INCHES	4·0 TONS.
3	 B.S.B. 4"·3"·9½ lbs/ft.	193 INCHES	48·0 TONS.
4	 BSB 4"·3"·9½ lbs/ft	193 INCHES	55·2 TONS
5	B.S.B. 5"·4½"·18 lbs PER FOOT RUN, SECTL AREA - 5·29"" LEAST I - 5·6	240 INCHES	12·7 TONS.
6	BSB 5"·4½"·18 lbs PER FOOT RUN, SECTL AREA - 5·29"" LEAST I - 5·6	240 INCHES	12·72 TONS.
7	 B.S.B. 5"·4½"·18 lbs/ft	240 INCHES	46·1 TONS
8	 BSB 5"·4½"·18 lbs/ft	240 INCHES	40·44 TONS

STEEL REINFORCED WITH CONCRETE: TABLE OF COLUMN TESTS.

The remaining four columns consisted of four precisely similar joist sections encased in concrete.

The columns were tested in a vertical position between the knife-edge bearings which form part of the equipment of the special testing machine. With these bearings the ends of the columns were perfectly free, and the columns were entirely devoid of any fixity of ends so that each column was tested in the simplest possible manner and free from all complications.

The first two steel columns tested were formed of naked 4 in. by 3 in. rolled steel joists by 9½ lbs. per foot run, the effective length of the columns between the knife-edge bearings being 16 ft. 1 in.

These two tests were followed by the testing of two precisely similar 4 in. by 3 in. rolled steel joists of exactly the same effective length, but each of these two latter columns were cased for their full length in concrete, making a compound column practically 8 in. square.

The average ultimate strength of the first two steel columns in their naked condition was 4·59 tons, whilst the average strength of the two compound columns of steel and concrete was no less than 51·6 tons. The ages of these two compound columns were respectively 164 days and 177 days when tested.

The next two columns to be tested were naked rolled steel joists 5 in. by 4½ in. section by 18 lbs. per foot run, with an effective length between knife-edge bearings of 20 ft. These columns were tested in exactly the same manner as has been described above, with the result that the average ultimate strength of the two columns was 12·71 tons.

Again two precisely similar 5 in. by 4½ in. columns by 18 lbs. per foot run were cased in concrete as before, making a compound column of steel and concrete 8 in. by 7½ in. in section, the covering of concrete in relation to the steel section being much less than in the previous columns. The average ultimate strength of these two compound columns was 43·27 tons. The ages of these two columns when tested were respectively 112 days and 119 days.

The concrete casing in the compound columns consisted of one part Portland cement, two parts sand, and four parts Thames gravel screened to pass a ¾-in. mesh and being perfectly free from sand. The cement was tested in the usual way, and was found to completely satisfy the British Standard Specification. The sand was of good character, clean and sharp, and free from dirt. The gravel was also clean and of excellent character.

No special precautions were taken in the manufacture of these steel and concrete columns, and the concrete was not rammed into the moulds ; it was merely worked round the joists with a shovel, the idea being to reproduce as nearly as possible the conditions frequently existing in ordinary building contract work.

To all appearance the concrete in these columns was quite equal to anything usually found in ordinary good work, but the results of tests of cubes of 7-in. sides and of circular prisms 8 in. in diameter by 16 in. long made of precisely the same concrete materials, and by the same labour during the making of the columns themselves, showed very variable results both as regards the compressive strength and also as regards the modulus of elasticity of the material.

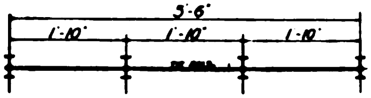
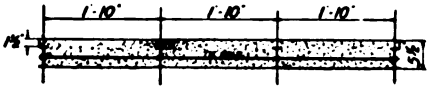
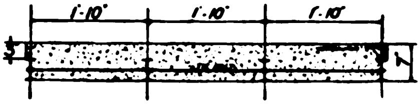
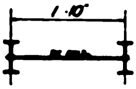
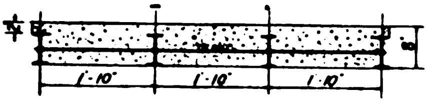
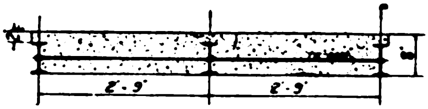
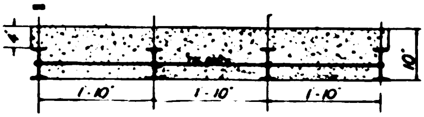
The crushing stress on the 8-in. diameter prisms 16 in. long varied from 1,110 lbs. per sq. in. to 2,850 lbs. per sq. in., whilst the modulus of elasticity varied from 711,000 lbs. to 2,100,000 lbs.

It is quite evident from the results obtained both in the column tests and in the prism tests that if the concrete had been rammed into place in the manner usually associated with first-class reinforced concrete work very much higher results would have been obtained.

In carrying out the tests at the National Physical Laboratory, the whole of the measurements and the recording of the same were made by members of the National Physical Laboratory Engineering Staff, and from these recorded results the following interesting comparison can be made :

The average strength of the first two naked steel columns 4 in. by 3 in. in section was 4·59 tons, while the average strength of the first pair of compound columns was 51·6 tons. From the measurements of actual compression under the loads I find that out of the total load of 51·6 tons the 4 in. by 3 in. steel joist section was actually carrying about half that total load, or 25·8 tons, the remaining half, also 25·8 tons, being carried by the concrete.

TABLE OF FLOOR SLAB TESTS.

MARK.	SECTION OF SPECIMEN.	DESCRIPTION OF SPECIMEN.
		SERIES .1. WITH 4"• 1¾" R.S.J. 9'0"
A.		4-4"• 1¾ JOIST FRAME CONNECTED AT ENDS BOLTS IN THE CENTRE. NO CONCRETE.
D.		4-4"• 1¾ JOIST- DO DO. FILLED WITH CONCRE WITH BOTTOM FLANGE AND 1½" ABOVE TO
F.		4 4"• 1¾" JOIST-DO DO FILLED WITH CONCR WITH BOTTOM FLANGE AND 3" ABOVE TO
		SERIES. 2. WITH 6"• 3" R.S.J. 14'0"
G.		2- 6"• 3 JOISTS CONNECTED AT ENDS AND BOLTS IN CENTRE NO CONCRETE
J.		4 - 6"• 3" JOIST FRAME CONNECTED AS ABOVE CONCRETE FLUSH WITH BOTTOM FLANGE ABOVE TOP FLANGE
L		3 - 6"• 3 JOIST FRAME CONNECTED AS ABO CONCRETE FLUSH WITH BOTTOM FLANGE ABOVE TOP FLANGE
K		4 - 6"• 3 JOIST FRAME CONNECTED AS A CONCRETE FLUSH WITH BOTTOM FLANGE 4" ABOVE TOP FLANGE

	COMPARISON OF RESULTS AT TEST LOAD.				
V	TEST LOAD ACTUAL	TEST LOAD REDUCED TO DISTRIBUTED OVER SPAN	INCREASE IN STRENGTH OVER PLAIN R.S.J. DUE TO CONCRETE.	DEFLECTION AT TEST LOAD. (2 POINT LOADING ONLY)	REDUCTION IN DEFLECTION OF SLABS, COMPARED WITH PLAIN R.S.J^s NOTWITHSTANDING THE ADDITIONAL LOAD APPLIED.
N TWO TIE	3·75$^{T.}$	7·5$^{T.}$	—	0·66"	—
FLUSH FLANGE.	D_1 { CENTRE LOAD 5·25$^{T.}$ D_2 { TWO POINT LOAD 7·85$^{T.}$	10·5^{T} (MEAN OF D_1 AND D_2)	+ 10%	0·35"	−47%
FLUSH FLANGE	F_1 { CENTRE LOAD 7·3$^{T.}$ F_2 { TWO POINT LOAD 10·4$^{T.}$	14·3^{T} (MEAN OF F_1 AND F_2)	+ 90%	0·295"	−55%
IN					
N 3 TIE	5 8^{T} (2 R S J^s)	7·73^{T} FOR 2 R.S.J^s { 11·59 " 3 " } { 15·46 " 4 " } VALUES IN BRACKETS BY PROPORTION FROM TEST OF 2.	—	0·90"	—
VITH IO 2'	16·0^{T}	21·3^{T} (4 R.S J^s)	+ 38%	0·58	−35%
WITH VO 2'	12·0^{T}	16 0^{T} (3 R.S.J^s)	+ 38%	0 55"	−39%
E WITH WO	21 5^{T}	28·6 (4 R.S.J^s)	+ 85%	0 395"	−56%

TABLE OF FLOOR SLAB TESTS.

It will thus be seen that by the mere covering of the steel joist with the casing of concrete the steel itself was carrying 5·6 times the load which had buckled the naked joist section, and the efficiency of the steel as a load carrier was thus enormously increased.

In the case of the 5 in. by 4½ in. joists a similar result was obtained, although not to the same extent owing to the covering of concrete being less in relation to the steel section, but the increase in the strength is still very important.

The average ultimate load which buckled the compound columns with the 5 in. by 4½ in. joists amounted to 43·27 tons, and I find from the measurements of compression that approximately 32 tons out of that load was being carried by the steel, leaving about 11 tons to be carried by the concrete. In this instance the carrying power of the steel was increased to 2½ times the strength which had been obtained in the tests of the naked column.

These results of the tests in themselves are sufficiently striking and remarkable. The accompanying table (see p. 758) shows the sections and the results obtained for each individual column.

TESTS ON FLOOR SLABS.

Mr. J. R. Sharman's report on the strength of steel joists embedded in a solid concrete floor slab is as follows:

In order to ascertain accurately the increase of strength due to the concrete, you had the following floor slabs tested by the National Physical Laboratory in a specially designed machine which you presented to the Laboratory. The machine will test slabs up to 14 ft. long by 6 ft. wide, and columns up to 20 ft. long, and the Laboratory has built a special house for it with an overhead crane and ample floor space for the preparation of test specimens. The tests were entirely carried out by the N.P.L. staff, who were responsible for the measurements, and the results are embodied in three reports and test diagrams received from them. The slabs tested and the results obtained, summarised from the N.P.L. reports, were as follows:

SERIES 1.—A steel frame composed of four 4 in. by 1¾ in. R.S.J. at 1 ft. 10 in. centres, connected at the ends and with two tie-bolts in the length, was tested on 9-ft. span (see sketch on Table on p. 760).

Two similar frames, but filled with concrete, flush on the bottom flanges and 1½ in. above the top flanges, making slabs 5 ft. 7¾ in. wide and 5½ in. deep, were also tested on 9-ft. span.

Two similar frames filled with concrete to 3 in. above the top flanges, making slabs 5 ft. 7¾ in. wide by 7 in. deep, were also tested, and the results are given in the Table.

A similar frame with concrete flush top and bottom was also tested, but showed little gain of strength over the plain joists, and is not included in the Table.

SERIES 2.—A steel frame composed of two 6 in. by 3 in. R.S.J. was tested on 14-ft. span. Slabs made up of four 6 in. by 3 in. R.S.J. with concrete flush top and bottom; 2 in. above top flange making 8 in. deep; 4 in. above top flange, making 10 in. deep; and a slab (L) 8 in. deep with only three 6 in. by 3 in. joists, were tested. The results are given in the Table with the exception of the slab with concrete flush top and bottom, which showed very little gain in strength over the plain joists.

The load was applied across the whole width of the slabs, either in the centre or at two points, and the Table gives the load reduced in all cases to distributed over the span.

Diagrams showing the deflections for small increments of load indicated clearly the limit of proportionality where the straight line on the diagrams commenced to curve away; this is referred to below as the "test load."

The test load given on the Table is the actual load at this limit of proportionality reduced to distributed over the span. The two frames of joists without concrete give a calculated stress at this point of:—Series 1, 13·8 tons per sq. in.; Series 2, 12·1 tons per sq. in.; the lower figure for Series 2 is due to a lower ultimate tensile strength—28 tons per sq. inch, as against 29 for Series 1—and also, being only composed of two R.S.J.'s, there was a tendency to buckle earlier in 2 than in 1.

The concrete was composed of 4 parts Thames gravel, 2 parts of sand, to 1 part of cement, mixed in the ordinary way, worked between the joists of the frames with a shovel and then levelled off. No special precautions were taken, with the idea of reproducing the conditions of work on an ordinary building contract. Tests of concrete cubes and cylinders made at the same time as the floors gave an average crushing strength of only 1,443 lbs. per sq. in., and an average modulus of elasticity of 1,250,000, showing the concrete to be below average quality. This, however, did not materially affect the strength of the slabs. See note (4).

The loads carried and the gain of strength due to the concrete are shown on the attached Table, and it should be noted that:

(1) In these test slabs only the centre joists are properly bedded in concrete on both sides. The two outside joists are not giving the same proportional gain, and therefore in a continuous floor with concrete on both sides of all joists, the condition would be more favourable than in these test slabs.

(2) Extensometer tests, giving the actual tension in the bottom flange of R.S.J. and compression in the concrete, were taken for specimens, J, K and L. At the limit of proportionality, the tension in the steel averaged for the three slabs was 15·2 tons per sq. in. and the compression on the concrete 920 lbs. per sq. in. This indicates that half the test load would give safe working stresses.

(3) In regard to deflection it should be noted that the concrete slabs are much stiffer than the plain joists. Although carrying heavier loads, as given on the Table, the deflection of the concrete slabs is approximately only half that of the plain joists.

(4) Referring to the strength of the concrete as given above, notwithstanding the low crushing strength it was sufficient to develop the limit of elasticity in the steel. By calculation, similar slabs, made with concrete having a crushing strength of 2,400 lbs. per sq. in. and a modulus of 2,000,000, indicate an increase of only about 5 per cent. in the load carried before a similar stress would be reached in the steel.

General Conclusions.—These tests indicate clearly a large gain of strength in rolled steel joists embedded in concrete when the top of the concrete is raised above the top flange of the steel.

Little or no gain of strength is obtained when the concrete is flush top and bottom with the flanges of the joists.

For every inch of concrete above the top flange the gain in strength over the plain joists is considerable; and this gain of strength continues to increase at a somewhat higher rate than the increase in thickness of the concrete above the top flange. For instance, comparing slabs D and F, 1½ in. of concrete above the joist give an increase of 40 per cent. over the plain joists, 3 in., or double the height of concrete, give an increase of 90 per cent., showing a gain in strength of more than double, and a similar relation holds with slabs J and K.

REINFORCED CONCRETE BEAMS IN BENDING AND SHEAR.*

It is good to have in permanent book form a copy of Dr. Faber's very important work upon the strength of reinforced concrete beams in bending and shear. Some of us have had an opportunity of seeing the results of the valuable experimental investigations which Dr. Faber has undertaken, but we doubt if many of the younger generation have studied this work in detail.

The book may be divided into two main portions. The first deals with experiments made upon the ultimate strength of reinforced concrete beams provided with varying percentages of single and double reinforcement, and the author here champions the orthodox theory. The other part of the book deals principally with the important though little-understood subject of shear, and here the author sets out to prove the orthodox theory to be wrong and points out what to him appears to be the better way.

As is typical of Dr. Faber's work there is a directness of attack about these beam experiments and a clear and novel method in interpreting the results that show a remarkably clear grasp of the subject under consideration. The author took a series of rectangular beams, made under practical conditions by workmen constantly engaged in reinforced concrete work (a very important feature), and varying only in the percentage of reinforcement. He tested these all to destruction and calculated the safe load for each upon the orthodox theory and accepted working stresses; he divided the ultimate load by the theoretical safe load and argues that if the resulting "factor of safety" comes constant the theory is correct. He finds that the factor of safety does come practically constant; it has a rising tendency, but he gives the full figures so that we can derive a suitable formula to provide for this increase if we wish.

The treatment upon shear is a very fine contribution to the literature of the subject; we confess that although at first we did not take very kindly to it we have become converted to Dr. Faber's point of view on this matter—his work, to us, has all had that quality; at first one reads it and his thought moves so quickly and his method of attack is so new that one does not grasp the argument at the first reading, but further study persuades one that here is something which must be considered. This is an indication of work that is going to last.

We strongly recommend engineers and students to read this book with care and to realise that there is often more to be obtained from original work emanating from this country than from the scissors-and-paste compilations that flow so freely from abroad.

The chapters include a Discussion of the Value of Tests to Destruction; Moment of Resistance of Singly-Reinforced Beams; Moment of Resistance of Doubly-Reinforced Beams; Shearing Resistance of Reinforced Concrete Beams; Shear Tests on T-Beams; Shear Tests on Continuous Beams; Shear Tests on Rectangular Beams. The volume is profusely illustrated with diagrams and half-tone illustrations totalling 113.—E. S. A.

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* *Reinforced Concrete Beams in Bending and Shear.* By Oscar Faber, O.B.E., D.Sc., M.Inst.C.E. 150 pp. Crown 8vo. (London: Concrete Publications Ltd. Price 9s. net.)

RECENT PATENTS RELATING TO CONCRETE.

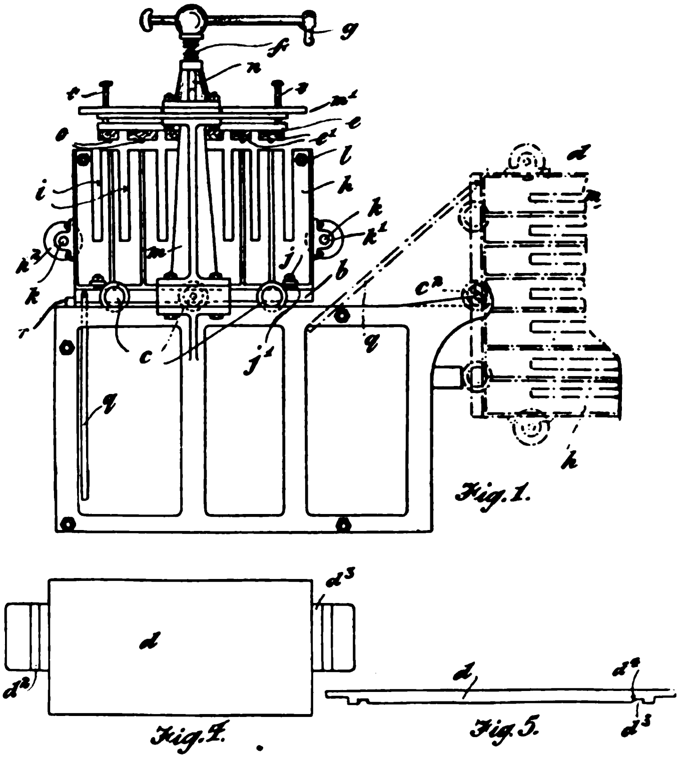
BLOCK-MAKING MACHINES.

[No. 211333.—H. McKinnon, 24, Apsley Street, Partick, Glasgow. Feb. 6, 1923.]

This machine is designed for the manufacture of concrete blocks, particularly breeze blocks, and comprises a box or mould formed of side members *h* which are slotted to receive division plates *d* for enabling a number of slabs to be made at one operation. The slots *i* in the side members do not extend to the full depth thereof, and the division plates are correspondingly shaped as shown in *Figs.* 4 and 5 to fit in these slots. The side members *h* are not rigidly secured to the base plate *a* but are connected to it by means of bolts passing through slotted holes, and the distance between the plates *h* can be adjusted by means of rods *k* having right and left-hand screwed ends. The necessary pressure is applied by a screw-operated press-plate *e* fitted with transverse bars e^1 which register with the space between the partitions. The base plate *b* is provided with three pairs of rollers, and the spindles c^1 of the central rollers project so as to register with notches c^2 formed near the end of the frame, thus enabling the mould to be tilted over to the position shown in dotted lines in *Fig.* 1 to enable the moulded slabs to be withdrawn on the partition plates. The bolts *k* are slackened prior to the withdrawal to enable the side plates to move clear of the blocks. Stops *r* are employed to limit the backward movement of the carriage and to ensure that it will occupy the correct position with regard to the press-plate operation.

CONCRETE MIXERS.

[No. 212163.—P. D. Ionides, Waterside Works, Ipswich, Suffolk, and Ransome Machinery Company (1920) Ltd., 14–16, Grosvenor Gardens, London, S.W.1. Sept. 8, 1922.]

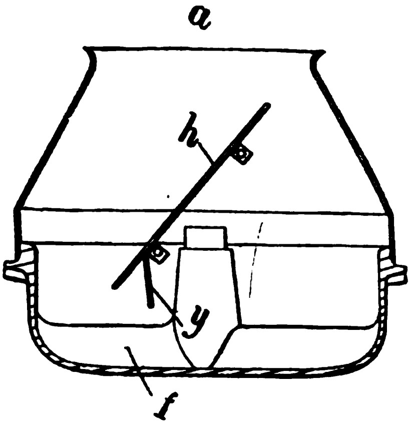


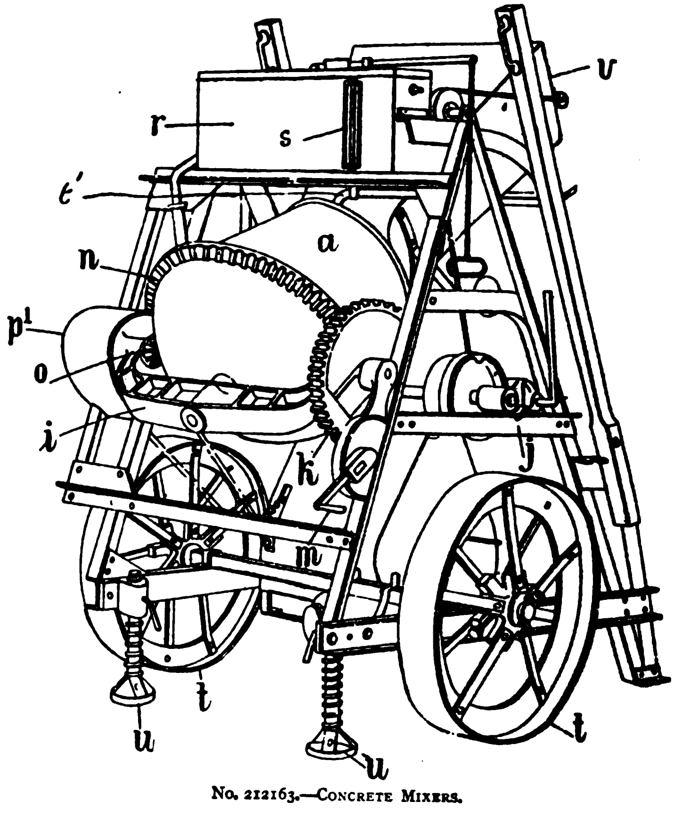
No. 211333.—Block-Making Machines.

The principal feature of the mixing machine made in accordance with this invention is that the rotary drum comprises a frusto-conical upper wall and an annular wall joining this upper portion to the base; the interior surface is curved so as to avoid flat surfaces in the bottom of the drum and sharp corners into which materials can lodge. The mixing drum has a number of mixing blades *h* diagonally arranged in the frusto-conical portion, and curved upstanding ridges *f* on the bottom which merge into the tubular bearing *e*. The drums *a* are driven by annular gearing *n*, and a water-supply tank *r* is arranged immediately above the drum so as to deliver quickly a measured supply of water into the drum immediately prior to tilting it to the mixing position during rotation. The frame *j* of the machine is mounted on two wheels *t*, which are so placed that their axes pass approximately through the centre of gravity of the machine, so making it more or less balanced on the wheels; for steadying the machine during the operation screw jacks *u* are provided.

ROAD REINFORCEMENT.

[No. 212328.—Major & Co., Ltd., of 12, Norfolk Street, London, W.C.2, and





No. 212163.—CONCRETE MIXERS.

W. Sangwin, Glynwood, Yarm Road, Stockton-on-Tees. Dec. 15, 1922.]

The double-system road reinforcement constructed in accordance with the present invention comprises an upper and lower layer of bars *g*, *h* at right angles to each other and vertical strut members *b* disposed at the crossing points of the horizontal members. These parts are preferably so connected that they may be collapsed for transport as indicated in *Fig.* 7. Diagonal members *d* or *e* can be arranged at intervals, and are put in position after the reinforcement has been extended from its collapsed form, although some of the diagonal members may be secured to the vertical members and collapsed with them.

CONCRETE BUILDING.

[No. 212477.—F. Bodson, 74, rue Jean d'Ardenne, Brussels, Belgium. June 27, 1923.]

This invention relates to concrete buildings of the type formed of pre-cast columns and beams which are filled in by slabs. One of the principal features of the invention consists in the manner in which the columns are secured to the foundations by casting a reinforced concrete foundation beam 10 between them. Foundation blocks 1 are provided with a groove 6 into which a reinforcing rod 8 is placed, and the mould for these beams may be formed by the slabs 3, the outer ones of which extend beyond the line of the columns 2. The columns are provided with transverse openings 5 through them, through which are threaded reinforcing rods, and which become filled with concrete, thus consolidating with the whole construction. The ends of the columns are formed with axial holes 11, 15, and the floor beams 12 are provided with a corresponding vertical hole which is caused to register with a hole 11 in the column over which it is placed. The reinforcing rod 14 is then placed through

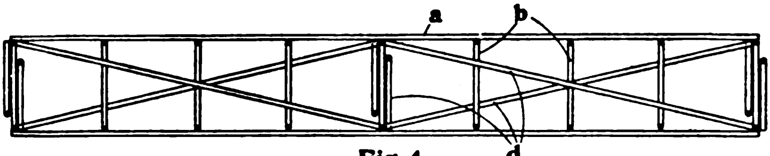


Fig. 4.

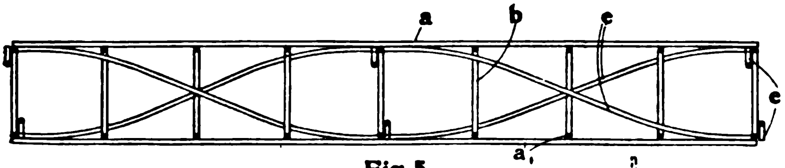


Fig. 5.

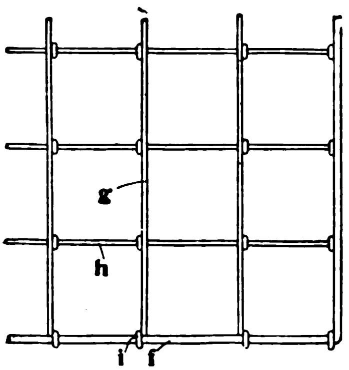


Fig. 6.

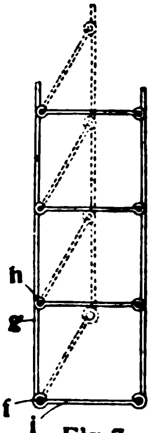


Fig. 7.

No. 212328.—Road Reinforcement.

the hole, which is then grouted up, and wall ties for these slabs may be laid into these holes as indicated. The upper length of column is then threaded over the projecting reinforcing rod, and the hole grouted up by grout introduced through a transverse opening 17. The tops of the columns are provided with a metal cap 20 forming two symmetrical faces which are fixed together by a bolt 21 passing through the columns and are provided with upwardly-extending wings 22 which are secured between in a slot in the roof timbers 24 by means of a bolt 23.

CONCRETE MIXERS.

[No. 214180.—John Fowler & Co. (Leeds), Ltd., and C. M. Wilcock, both of Steam Plough and Locomotive Works, Leeds, Yorks. Dec. 22, 1923.]

The present invention comprises an improved method of construction of the drum of concrete and like mixers, the object being to produce a lighter drum than has hitherto been used, thus requiring less horse-power to drive it. The improved drum consists of a cylindrical body *A* which is formed of semi-cast steel and is provided with an exterior circumferential beam to which the driving crown pinion *C* is riveted or otherwise secured. The drum heads *D*, D^1 are formed of light pressed steel and are curved so that their edges fit within the body *A*, to which they may be riveted. Six or other convenient number of pressed steel members *E* are fixed around the inside surface of the drum body, these being formed with other portions E^2 and bucket portions E^1.

FIG. 1

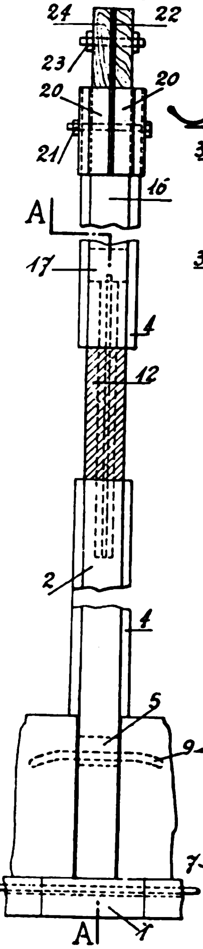
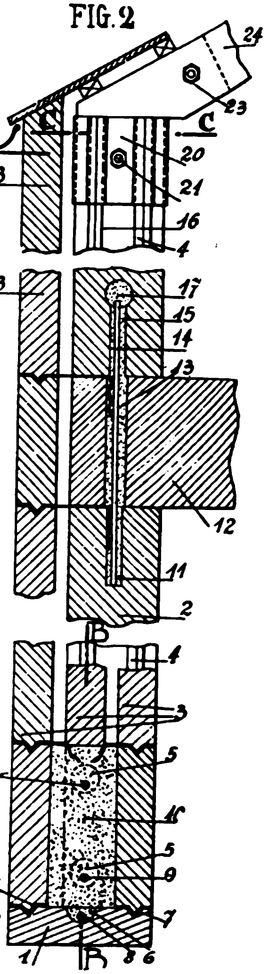
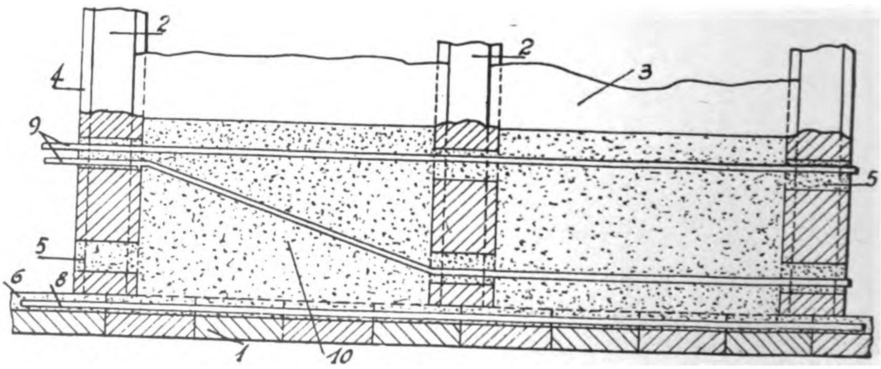
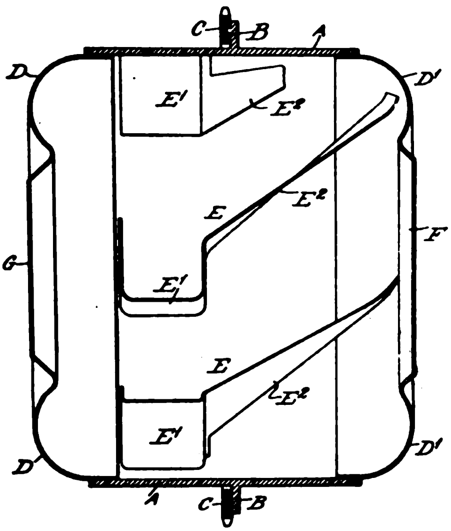


FIG. 2





No. 212477 —Concrete Building.



No. 214180.—Concrete Mixers.

CONCRETE MIXERS.

[No. 214482.—A. Hiley, H. Thomson Garvie and E. Le Bas, Dock House, Billiter Street, London, E.C.3. May 30, 1923.]

The object of this invention is to provide means for giving a vibratory or reciprocating motion to the skip to assist it in discharging its contents into the drum or the like of the mixer. A mixing drum *a* is provided with its orifice conveniently disposed near to and between the two vertical columns *b* of the frame *c*. Two struts *d* are placed between columns *b* and supported laterally by struts secured to the two channel guides *e* fixed to the frame. On the channel guides *e*, the skip *g* is adapted to run by means of its rollers *h* and *j*, of which the latter are mounted on an axle *k*. On the frame *c* is mounted a shaft *m* carrying a cam or ratchet wheel *n* at or near each end with a plurality of teeth or projections. On each channel guide *e* is a hinged head *o* provided with a pawl *p* adapted to be lifted by teeth or projections on the cam or ratchet wheel *n* and so receive a vibratory or reciprocating motion. The pawl *p* is a lug on an extension *q* of the head *o* on a vibrator bar or beam adapted to strike a plate or anvil *r* on each strut or post *d* which takes the blows thereof, which are imparted thereto by the impact of the skip. Assuming the skip *g* to be loaded in position at the bottom of the channel guides *e*, the hauling means is set to work and the skip hauled up to the top of its run and tipped. The weight of the skip brings down the vibrator bar or beam and pawls *p* on to the teeth or projections of the cam or ratchet wheel *n*. The shaft *m* has been previously set rotating, and the consequent rotation of the cam or ratchet wheels *n* imparts to the pawls *p*, and therefore to the anvil heads *q* and vibrator bar, a vibratory or reciprocatory motion which is transmitted to the axle *k* and so to the skip *g*. As the heads *o* are hinged to the channel guides, and the plates or anvil heads *p* are controlled and prevented from taking any appreciable lateral movement, the only appreciable vibratory motion imparted to the skip

Fig. 1

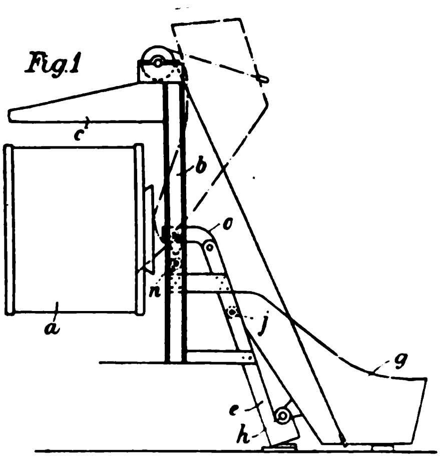
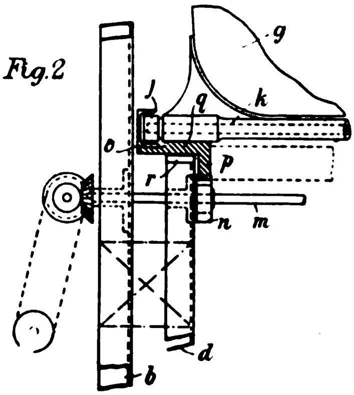


Fig. 2



No. 214482.—Concrete Mixers.

Fig.1.

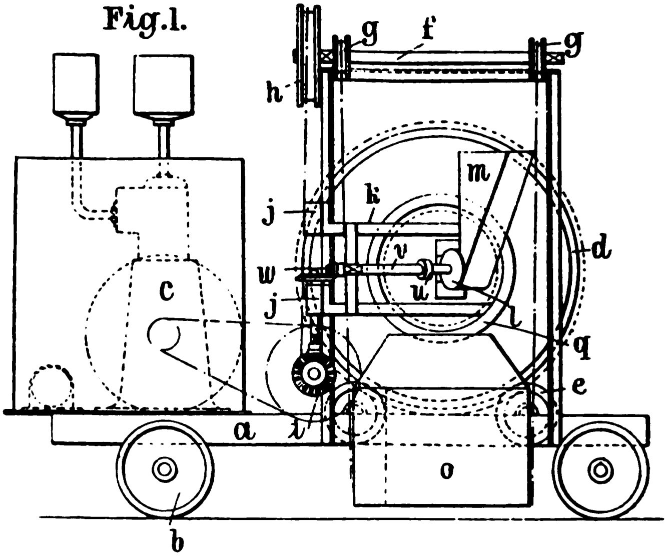
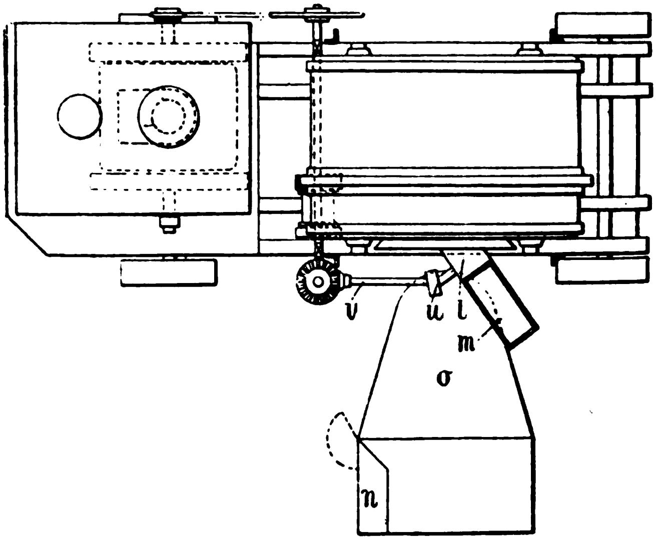


Fig.2.



No. 215093.—Mixing Machines.

is substantially vertical, and this imparts a shaking motion to the contents of the skip which much accelerates the rate of discharge.

MOULDS FOR CONCRETE BLOCKS.

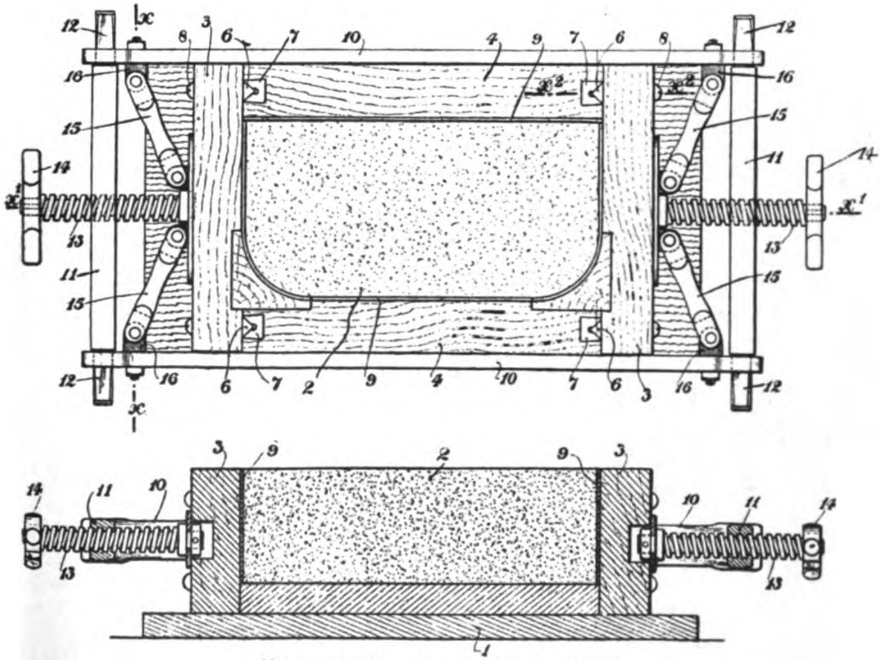
[No. 214359.—A. E. Worsley, 73, Ashby Road, Tamworth. Feb. 1, 1923.]

The improved forms for concrete blocks made in accordance with this invention have end members 3 and side members 4 which are connected together by V-shaped bars 6 resting in correspondingly grooved bars 7; the end members 3 are operated by screws 13 passing through end bars 11, and the side members 4 are carried by side plates 10 which are connected by links 15 with the end members 3. The arrangement of parts is such that when the screws are operated all four members move away from the moulded work, the V-shaped parts 6, 7 enabling this movement to take place. A modified construction is described in which the members forming the mould are withdrawn successively instead of simultaneously.

MIXING MACHINES.

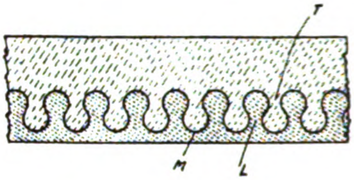
[No. 215093.—P. D. Ionides and Ransomes & Rapier, Ltd., Waterside Iron Works, Ipswich. Feb. 2, 1923.]

This invention provides a batch mixer in which each batch of aggregate is first moistened and afterwards incorporated with cement, which is introduced into a rotating mixing drum in the form of a fine spray or cloud whereby each particle of the aggregate becomes uniformly coated with the cement. The frame *a* carries an oil or other power unit *c* for driving the whole machine, and supports a mixing drum *d* mounted on rollers *e*. The upper portion of the frame *a* supports a shaft *f* having pulleys *g* thereon, the shaft having also a pulley *h* driven from a shaft *i* supported on the frame and operated by the engine *c*. Pivotally mounted at *j* on the frame *a* is a support *k* carrying a cement sprayer *l* connected by a universal joint *u* to a shaft *v* which is adapted to be operated by gearing *w* from the shaft *i*, suitable clutch or other mechanism being provided between the sprayer *l* and the shaft *i* whereby the sprayer may be operated as and when desired. Associated with the sprayer *l* is a cement hopper *m*, which is supplied



No. 214359.—Moulds for Concrete Blocks.

with cement from a compartment *n* in a loading skip *o* when the skip has been raised into the loading position. In operation the aggregate is charged into the skip *o* and the cement into the compartment *n*. The cement sprayer *l* is then swung clear of the admission opening in the drum *d* and the skip *o* hoisted by the pulleys *g* to the charging position. The aggregate then passes into the drum through the opening therein, and the cement simultaneously passes into the hopper *m* associated with the sprayer *l*. Water is then fed from the tank *t* into the drum *d* thoroughly to wet the aggregate in the drum, after which the water is shut off and the sprayer *l* swung into the operative position and connected to the shaft *i*. As the aggregate is thrown about the mixing drum by the rotation of the drum the cement is sprayed on to the aggregate in the form of a fine mist or cloud, whereby every particle of the aggregate becomes uniformly coated with cement. On completion of the mixing operation the discharge chute *s* is brought into operative position and the concrete discharged from the drum *d*. The formation of pockets of cement is avoided.

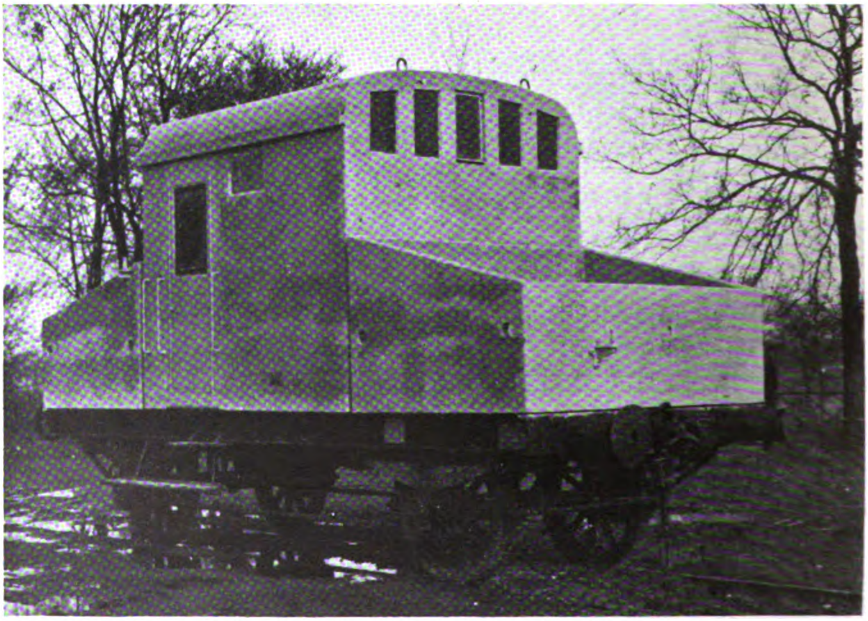


No. 214902.—Reinforcement.

REINFORCEMENT FOR CONCRETE.

[No. 214902.—W. S. Peggs, "Roxwell," Connaught Av., Chingford. Aug. 29, 1923.]

The reinforcement according to this invention consists in metal sheets corrugated in sinuous curves, the sides of which approach each other alternately near the top and bottom faces, so forming a set of narrow necked openings or grooves to key the concrete or like material. When used for floors or roofs concrete is applied on the top of the corrugated sheets and enters the constricted entrances *T* of the sheets *M*, and the underside of the metal can be plastered to form a ceiling, the plaster entering the constricted entrances *L* and being keyed by the portions of the corrugations.



French Concrete Crew Car.

[Reinforced concrete is specially used for these cars on account of its weight, which prevents the cars from "jumping" the track when running light. The cost is about 5,000 francs cheaper than wood and metal.]

PERFECTION IN ROAD CONSTRUCTION.

By J. H. WALKER, M.Inst.C.E.

It is a fact beyond dispute that any road crust made of a material that has little compressive strength when either hot, cold, wet, or dry must inevitably develop corrugations when subjected to ordinary atmospheric conditions and the hammer-like blows of continual fast and heavy traffic. Such corrugations inseparable from crusts of waterbound macadam or tar and asphalte compounds are seriously detrimental to motor vehicles and the comfort of all road users.

In concrete we have an ideal material for road construction inasmuch as it has great compressive strength under all weather conditions, and consequently does not corrugate. It, however, has physical characteristics which, if not allowed for in design, will give faults comparable with corrugations in resultant inconvenience to traffic. Without going too deeply into the matter it will suffice here to state :—

(1) A concrete surface will not corrugate.

(2) A large concrete slab, however strongly reinforced, laid continuously without joints on an earth formation, will crack tranversely and longitudinally. At such places the steel spanning the cracks will either be broken through or will in course of time rust away and grooves or channels will form at the surface of the cracks. Such grooves, with bad maintenance, may be enlarged by the traffic into dangerous holes difficult to repair efficiently.

Cracks are an abomination and a sign of bad engineering. Until recently many engineers unacquainted with methods of concrete road construction whereby cracks are eliminated professed to look upon such cracks with tolerance. The statement was often made that though unsightly cracks were not harmful.

General opinion has now changed. In some cases cracks, which were negligible in the first year or so of the life of a concrete road, have increased in number and size and have also grooved and channelled at the surface. Such cracks and grooves are difficult to maintain. Any filling material put into the grooves in winter when the cracks are open is forced out in summer when the concrete expands and the cracks close. It will be obvious that water must lodge in a crack, and in time rust away the steel reinforcement, whether the latter be uninjured or whether it be perhaps broken across at the time the crack originated.

With increased experience and knowledge, many who previously advocated laying concrete roads in the so-called continuous method have now adopted the alternate bay method. In a few instances straight vertical joints are employed, whilst in a few others the steel reinforcement is carried through the joint. In either case surface grooving at the joints is inevitable, the only remedy being to interlock the adjacent slabs with non-corrodible material, such as concrete. To rely on steel reinforcement through a joint is useless and a waste of time and money.

(3) A reinforced concrete slab laid in the alternate bay method but with plain vertical joints and no steel reinforcement connecting adjacent bays will :—

(*a*) Not corrugate on the surface.
(*b*) Not crack.
(*c*) Groove and channel at the surface of the joints, which grooves will develop into holes and necessitate continual patching and repatching as the joint opens and closes.

(4) A reinforced concrete slab laid as in (3) but with steel reinforcement spanning the joints must in time, as the steel breaks or rusts at the joints, develop grooving and channelling as is stated in (3) (*c*).

(5) A reinforced concrete slab properly laid in the alternate bay system with interlocked joints will :

(*a*) Not corrugate on the surface.
(*b*) Not crack.
(*c*) Not groove or channel at the surface of the joints.

But the surface, if not protected with a renewable thin spray carpet, will in the course of years show wear due to the traffic. This wear would, of course, take place even if the surface were of rustless steel, and to make it good necessitate inconvenience to traffic.

(6) A thin bitumastic spray carpet sprinkled with grit or granite chippings

properly applied to a suitable concrete surface, lightly washed and broomed free of laitance, will adhere perfectly and last, as has been proved under fast, heavy traffic, for four or more years. The resulting long life of such thin carpets compares favourably with the present necessity and expense of tar spraying other types of road once or twice every year.

(7) If the aggregate of the surface concrete be large, like that usually used in water-bound macadam roads, the appearance of the road surface will be identical with that of the tar-sprayed and gritted macadam road, than which, when free from corrugations in the first few weeks of its life, there is no better for motor and horse traffic and absence of glare on a sunny day.

A very common practice is to use small aggregate in the surface concrete.

This has many disadvantages, viz.: (1) Each stone being small has only a shallow bedding in the mass and is easily loosened by a blow before the concrete has matured. Consequently it is inadvisable to wash and broom off the laitance shortly after the concrete is set. (2) Should it be desired to bitumen-spray and granite-chip the surface it is difficult to get such a carpet to adhere to a surface from which the laitance has not been removed. (3) Heavy iron-tyred traffic will easily snap in two a small stone, leaving it ready to be sucked out by rubber-tyred traffic. (4) Due to the size of the aggregate a considerable time must be allowed for the concrete to mature before traffic can be put on the surface.

Great success has been attained with large granite aggregate broken to pass through a 2½-in. ring and be retained on a 1½-in. ring. The surface concrete is composed of 3 of such aggregate, 1½ sand, to 1 of cement.

Such a surface has the following advantages:

(*a*) Each stone forms part of a hard-wearing granite-mosaic surface and is deeply embedded in the mass concrete; consequently, such surface can without harm be lightly washed and broomed free of laitance 24 to 48 hours after laying.

(*b*) To such a washed and broomed surface a thin tarvia or bitumen-spray carpet sprinkled with granite chippings will adhere perfectly without any tendency to peel off. Such carpets after four years' wear under fast and heavy traffic are still in good condition.

(*c*) With a surface of large granite aggregate the traffic can be turned on to the road in a comparatively short time after the concrete is set. The only precaution usually taken is to cover the concrete with sand, ashes, or oak bark.

(*d*) Such a surface is exactly similar to good tar-sprayed waterbound macadam and is identical with it in giving a good foothold for horses and a non-skidding surface for motors. The difference between the two is that the latter corrugates and the former does not.

The use of small aggregate in concrete road surfaces would appear to originate in the early makers of concrete roads following on the precedent of granolithic surfaced floors in sheds and quays, where there was usually plenty of time for the concrete to set and the surface was left uncarpeted. Such a surface was required to be perfectly smooth for the running thereon of hand trucks with small iron wheels. This close adherence to a precedent for a dissimilar service is remarkable when one considers that large-size aggregate is preferred in waterbound and tar-bound roads on account of its superiority over small aggregate; such superiority is due to its greater ability to stand hard wear on account of the largeness of the stones and their being more deeply and firmly embedded. Merely because the macadam is cement-bound instead of water or tar-bound would hardly seem to warrant the following of a precedent for shed floors instead of road construction.

Actual experience of constructing roads with both classes of aggregate is unquestionably in favour of using the large size for fast and heavy traffic, including steel-tyred vehicles. If the concrete of the lower layer be used as it should be with a minimum of water no difficulty will be found in obtaining a granite-mosaic surface of large-size aggregate.

In spite of all the experience now gained it is a matter for great regret that there should still be many mistakes made in concrete roads. Such roads properly constructed are without doubt the economical roads of the future. Properly designed and constructed they have perfectly plane surfaces and withstand the combination of varying atmospheric conditions and fast and heavy traffic without developing faults. It is fortunate that, even with mistakes in design, concrete roads stand supreme in the science of economical road construction in that they are free from the evils of corrugations; therefore the construction of imperishable roads, perfect in every respect, is merely a matter of time. In a few years engineers will learn to avoid errors in construction, either from their own experience or, more cheaply and earlier, from the experience of others.

An instance of such a mistake is the laying on concrete surfaces of bitumastic coverings of thicknesses of 1 or 2 ins.; these coverings, having little compressive strength when hot, must inevitably corrugate in summer with or without fast and heavy traffic, and detach themselves more or less from the concrete base. The visible evidence of repatching on such roads should be a sufficient warning to others contemplating similar misuse of concrete slabs. Such bitumastic coverings when used should be sprayed or brushed on as thin as possible in order that with the inevitable expansion in hot weather the resulting corrugations in even so thin a carpet as an eighth-of-an-inch thick shall be of so small a pitch as to be invisible.

NEW REINFORCED CONCRETE BRIDGE OVER THE THAMES.

THE work of demolishing the Albert Bridge over the Thames near Datchet, and constructing a new one in its place, will commence in a few days. The new bridge, which will be constructed in reinforced concrete, is of Renaissance style, but with squared rubble towers to avoid conflict with the Norman architectural surroundings.

The design, prepared by the County Surveyors of Berks and Bucks, was approved by His Majesty the King, and the bridge when completed will bear the Royal Arms.

The illustrations on pp. 776–7 show (1) the existing Albert Bridge, and (2) the proposed new structure.

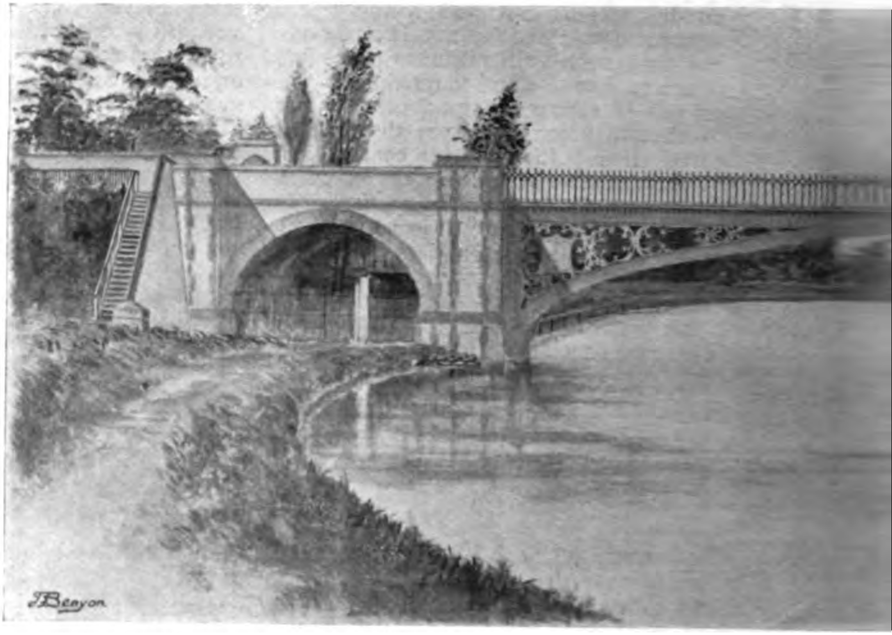
The present bridge which took the place of the old Datchet bridge was rendered necessary by a road diversion. The original Datchet bridge was built by Queen Anne in the year 1706, and rebuilt by the Crown in 1775. In the year 1795 the bridge fell into decay and became impassable, the wooden part was taken down by King George III and the material sold. From that time a ferry was constantly employed at great expense to the Crown, no toll being demanded.

Many attempts were made to compel the counties of Berks and Bucks to reinstate the bridge, but they were obdurate. However, through the spirited exertions of one John Richards, in 1810 the two Counties were compelled to reinstate the bridge, and it was opened for public use in the early part of January 1812. When it became necessary to strengthen this bridge the two Counties could not agree upon the design, and in 1837 the County of Berks rebuilt their portion in iron, the two structures, one of wood and the other of iron, being clumsily joined in the middle.

The present bridge in Gothic style was designed by Prince Albert and was erected in 1852. It consists of stone tower abutments and wing walls faced with squared rubble; a one-span arch composed of ornamental cast-iron ribs; iron road-girders and brick jack-arches; ornamental cast-iron railings; and on the Bucks side brick land-arches. In 1852 Sir W. Cubitt certified that the bridge was built in a proper and substantial manner, but, although at that time doubtless more than sufficient, it is not now capable of taking present-day traffic. The cast-iron arch-ribs are cracked in various places due to contraction in casting, temperature, or vibration stresses and the bridge has dropped at the arch crown.

In 1914 the County Surveyors of Berks and Bucks reported to the Berks and Bucks Joint Committee concerning the safety of the structure and gave details of borings, etc., and eventually it was resolved to construct a bridge capable of taking all classes of modern traffic. A

(*Continued on p.* 778.)



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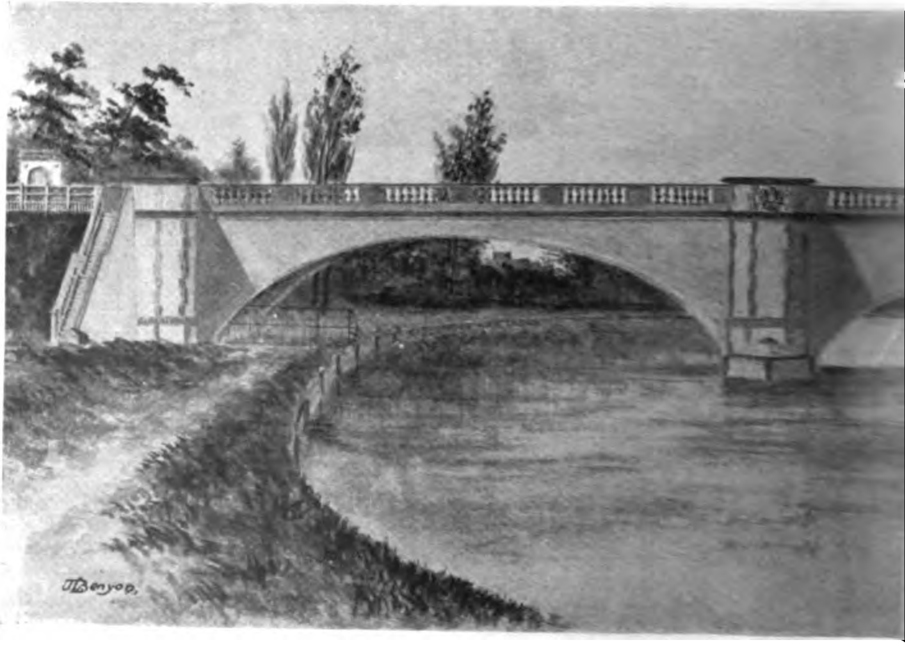
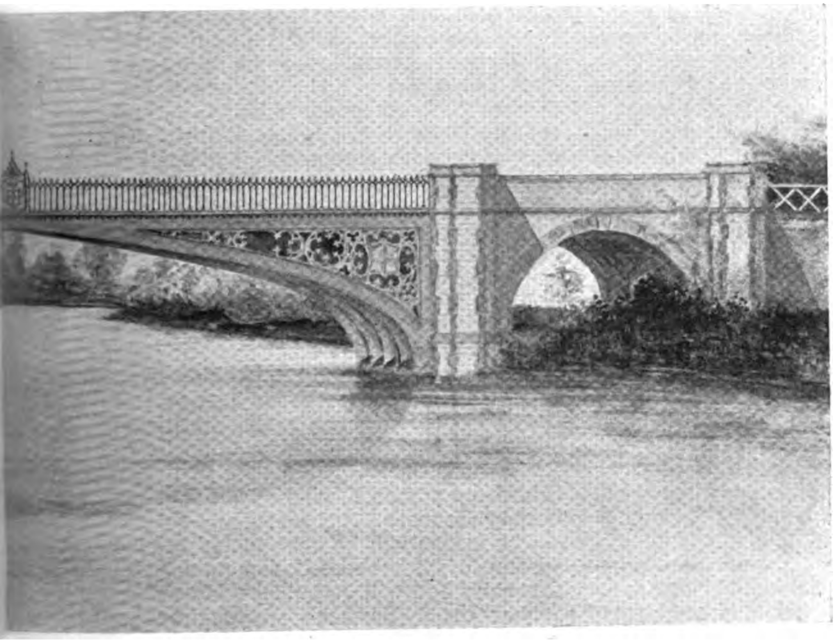


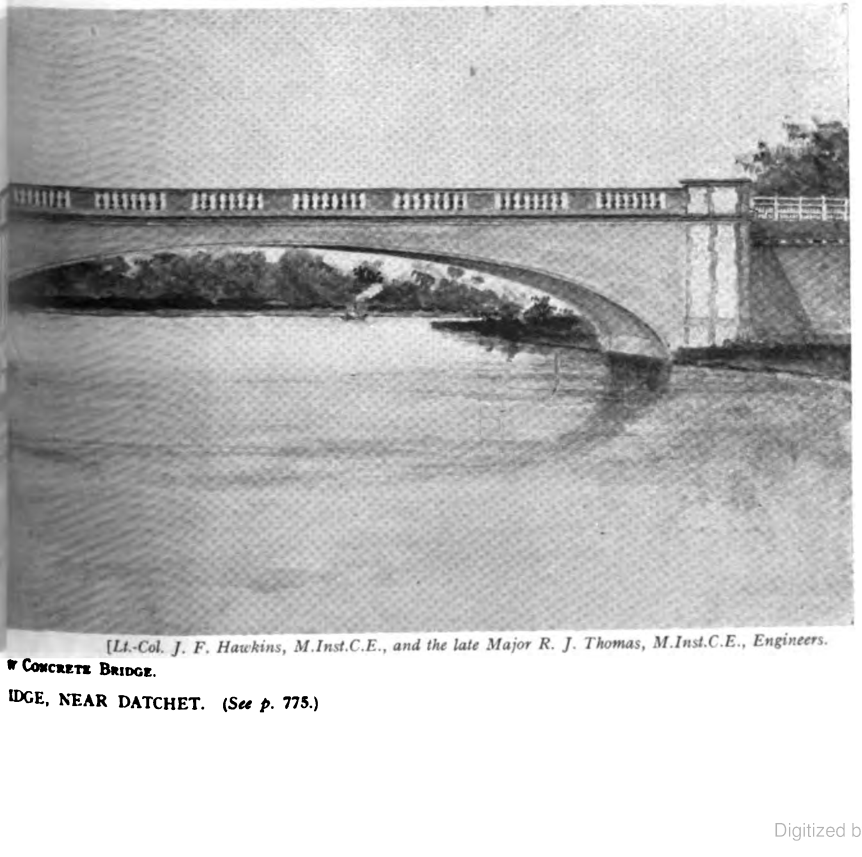
The Design for the N

RECONSTRUCTION OF THE ALBERT B

NEW CONCRETE BRIDGE OVER THE THAMES.



RIDGE.



[Lt.-Col. J. F. Hawkins, M.Inst.C.E., and the late Major R. J. Thomas, M.Inst.C.E., Engineers.

W CONCRETE BRIDGE.

IDGE, NEAR DATCHET. (*See p.* 775.)

ferro-concrete bridge was decided upon, but there were difficulties to be met, chiefly with the Thames Conservancy, as to the width of waterway at this important point on the river. However, at a later date the width of waterway was agreed, and the new bridge will consist of two unequal span arches, the arch on the Berks side being 75 ft., and the arch on the Bucks side 110 ft., with a centre cut-water pier 15 ft. wide.

The arches will be of slab construction on which will be carried, by means of columns, the deck beams and decking. The balustrading and cornice will be of Bath stone, supported by reinforced concrete curtain walls which are so arranged as to be independent of the arch slab and decking. The towers and wing walls will be faced with squared rubble and stone dressings from the old bridge ; seats will be arranged in the towers at footpath level as at present.

As an engineering structure the bridge is of interest. The arches are designed as two hinged arches to allow of movement through uneven loading and changes in temperature on account of the unequal spans to determine on the centre pier the points through which the lines of thrust must pass, etc., without overstressing the concrete and steel. This will be the third reinforced concrete bridge to be erected over the Thames. The engineers, Lt.-Colonel J. F. Hawkins, M.Inst.C.E., and the late Major R. J. Thomas, M.Inst.C.E., were faced with a number of difficulties owing to the requirements of the different authorities concerned, but in spite of this a pleasing structure has been devised and, at the same time, one capable of taking the heaviest modern traffic.

From March 1915 until 1920 matters were held in abeyance. In 1920 tenders were obtained, but it was not until June 1923 that the Joint Committee resolved to proceed with the work. The cost of the bridge will be borne by the Ministry of Transport and the County Councils of Berks and Bucks, and when built the future maintenance will fall on the two County Councils.

The bridge will be constructed on the system of the Trussed Concrete Steel Company and will be built by Messrs. A. Jackaman & Son, of Slough, Bucks, under the superintendence of Lt.-Colonel J. F. Hawkins, County Surveyor of Berkshire, and Mr. E. Winfield, County Surveyor of Bucks.

CONCRETE PRODUCTS.

MOULDING CONCRETE PRODUCTS.

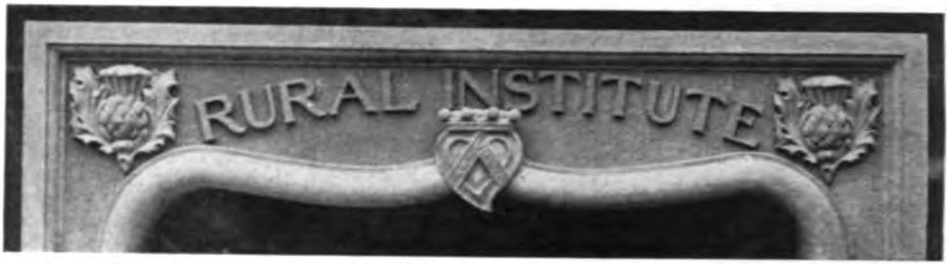
SOME interesting particulars of American methods of moulding figures and other forms in concrete were given recently by Mr. R. F. Havlik before the American Concrete Institute. After an account of the methods of the modeller in reproducing the desired form in clay or wax, he said:

If the piece is to be reproduced in a glue mould it must be shellaced thoroughly with orange shellac. The purpose of this is to keep the moisture in the clay from ruining the surface of the glue. If the model is to be reproduced in a plaster mould this treatment is not necessary. The next step in making a glue mould is to place a thin layer of clay over the entire model. The thickness of the clay should not exceed ¾ in.; this is later replaced with glue. The next step is to coat this with a thin layer of pure moulding plaster of Paris of the best grade obtainable. This must be worked so that the plaster does not harden before this section of the mould is completed. The next step is to built up the section with fibre dipped in plaster of Paris. The fibre is used to reinforce the plaster. Should the mould crack the fibre will hold the pieces together. It is the cheapest material obtainable for this purpose. The fibre used can be purchased from leather tanneries and consists of the scrapings of hides, the surface of coco-nut shells, and rope hemp. The plaster is mixed by partly filling a dish with water and then scattering a handful of plaster at a time over the entire surface of the water so that it will absorb the water quickly and not form lumps. This should be continued until the plaster shows up at the surface of the water. It should then be stirred with the hand or a large spoon until it is of a creamy consistency.

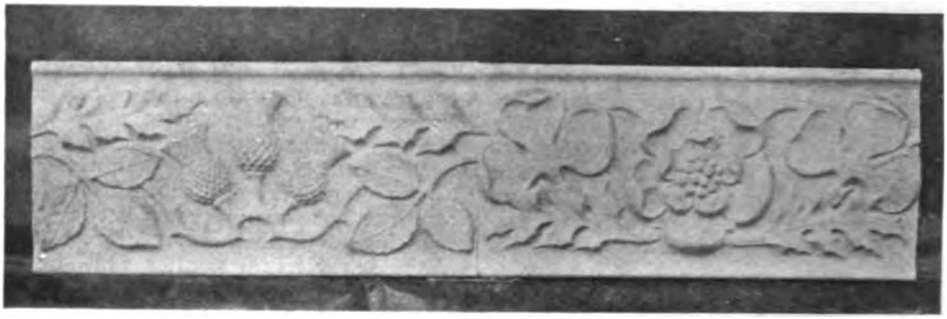
When the section of the plaster jacket sets, the plaster partition surrounding it is removed. The edges of the section are then trimmed off smooth, and joggle holes are cut into each edge. The edges are then shellaced and greased and the next section is built in the same manner.

The next step is to remove the plaster jacket from the model. When this is done the clay surrounding the model will usually adhere to the sections of the jacket. The surface of these plaster jackets is then scraped and trimmed as smooth as needed. They are then thoroughly shellaced and all the sections of the jacket and the model are then greased. The grease commonly used is made of kerosene and stearine wax mixed in the proportion of four parts of kerosene to one part of wax. The jacket is then reassembled around the model and clamped with clamps or fibre and plaster ties across the joints. A funnel is then set over the top of the mould and held in place with a fibre and plaster tie. The mould is then poured full of hot glue. The glue used is known as "casting glue," in flake form, and is prepared for use as follows: The amount of glue required for the mould is placed in a tub or pail and covered with water. After about five minutes all the water is strained off as well as possible, through a "gunny sack" or screening. The glue is then placed in a steam or hot water jacketed kettle until it melts. It is then allowed to cool for about thirty minutes, after which it is poured into the mould. The mould is then allowed to stand overnight to allow the glue to cool and harden. The following day the clamps or plaster ties are removed and the jacket loosened by driving an ordinary wood chisel into the joints of the mould. The glue jacket is then cut through to the model on the lines corresponding with the joints in the plaster jacket. The pieces of glue are then removed from the model and the model can be destroyed or set aside for further use.

The next step is to powder the surface of the glue with French chalk. This is rubbed into the surface with a dusting brush. The purpose of this is to remove all grease from the surface of the glue. The glue is then thoroughly painted with a saturated solution of powdered alum and water. This is done to harden the surface of the glue. The glue is then allowed to dry for two hours or so and is then painted with a paint of the consistency of cream, made up of litharge, linseed oil, turpentine and Japan drier, mixed in equal parts of each ingredient. This paint is then allowed to dry on the



A Concrete Lintel.



A Concrete Frieze.

Concrete Lettering.

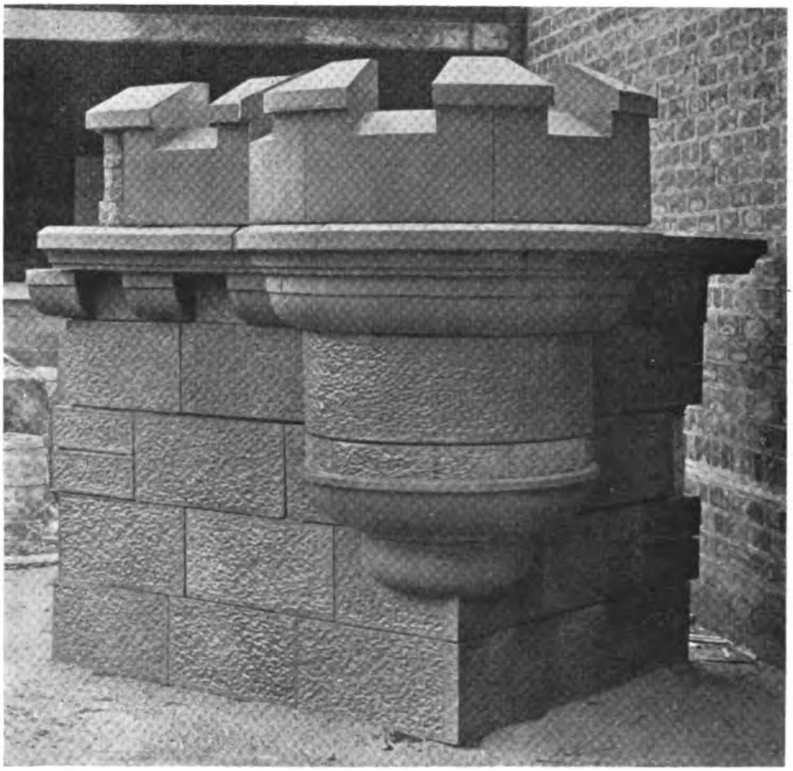
DECORATIVE CONCRETE.

[The cast concrete stonework on this and the following pages was made by Mr. Alexander Walls, of Thistle Street, Stirling, for use locally.]

glue twelve hours, or overnight, and will thoroughly waterproof the surface of the glue. Without this treatment only one or two good casts could be produced with a glue mould, whereas moulds so treated can often be made to produce as many as ten or twelve casts. Some manufacturers use white lead paint and heavy varnishes for the same purpose, but litharge paint gives the best results.

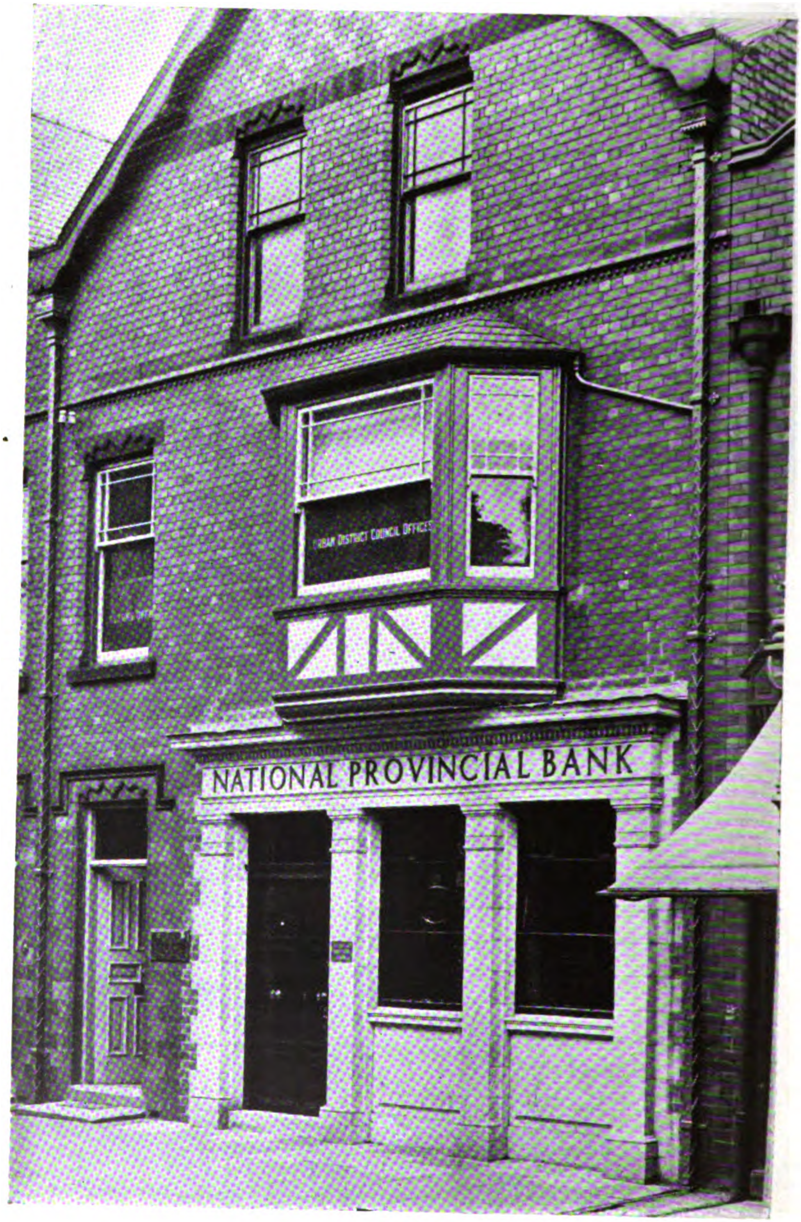
After this treatment the mould is ready for the production of concrete casts. The concrete should be mixed to a slushy consistency so it will run freely enough to get into all the details of the moulds. It is best to make it as dry as possible, but the driest mix used usually is what would be termed at least "sloppy." In warm weather the mould can be removed from the product the following day, but in cold weather it is best to leave it in the mould for two days or longer. The product should then be steam cured for at least two more days, after which it can be surface treated. When the cast leaves the mould it usually has some defects, in which case it should be pointed up with the same mixture as was used in the original cast. This can be done either before or after it has been steam cured. If done after it is steam cured, the product should be put back in the kiln for at least another 24 hours. The best way for surface treating the product is then to dip it in a solution of muriatic acid and water. The product has to remain in the acid solution for three minutes to an hour—depending on the age of the product, the effect that is desired, and the material that is used.

Any piece produced in a glue mould can also be produced in a plaster piece mould. In producing a plaster mould the problem is somewhat similar to the manufacture



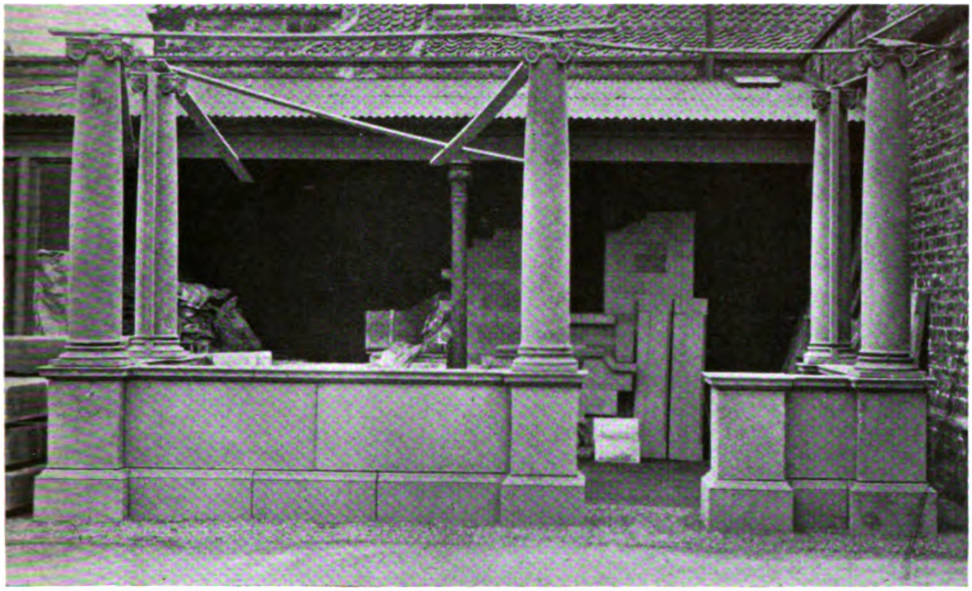
A Lunet in Concrete.

[Made by Mr. Alexander Walls, Stirling.]



A CONCRETE BANK FRONT.

[Made by Mr. A. E. Reney, of Connah's Quay.]



Concrete Stonework for a Verandah.

[Made by Mr. Alexander Walls, Stirling.]

of a glue mould. The first step, however, is to build a small section at a time that will draw freely from the model. This section should be made as large as possible, but if the model is highly ornamented it will usually be very small—sometimes just a few inches in each direction. A mould for a small Ionic cap for a 12 in. column may consist of 30 to 35 pieces in all. A clay partition is built up in the same manner as for a glue mould, and a section made of plaster reinforced with fibre. When one section is completed the surrounding clay partition is removed and a similar partition built around the adjoining section. This section is produced in the same manner until the entire model is surrounded with small pieces of plaster, all of which will draw freely from the model.

The pieces of the mould are usually marked to indicate the order in which they should be removed from the cast and reassembled again in the mould. These pieces, when completed, are surrounded with a casing of plaster to hold them in their correct positions. The edges of each piece of the mould as it is made are shellaced, as described for the glue mould, and when the entire mould is completed all inside surfaces of the mould are shellaced and greased. The mould is then filled with concrete in the same manner that glue moulds are poured.

When only a few pieces are to be made from a given mould it is usually more economical to make a glue mould for the purpose, rather than a plaster mould. If a large number of pieces are to be made from the same mould it may be more economical to use the plaster mould instead. If a given piece is highly ornamented, a glue mould can usually be produced for half the cost of a plaster mould. The further advantage of a glue mould over a plaster mould is that there are less joints in the mould, and consequently a lesser number of seams in the finished cast that have to be removed and pointed. This means that the actual manufacturing cost of the concrete cast is less in a glue mould than in a plaster mould. In producing stone that must be true in all dimensions to the plans, great care must be taken that the lines of the mould are correct and that the glue does not become too soft, else the mould will bulge and the cast be out of shape.

CONCRETE COTTAGES FOR THE WAKEFIELD CORPORATION.

Two hundred concrete houses are now being erected for the Wakefield Corporation, to the design of Mr. Percy Morris, City Housing Architect, with a system of concrete blocks and slabs which does away almost entirely with the services of the bricklayer, and also considerably decreases the work of the plasterer.

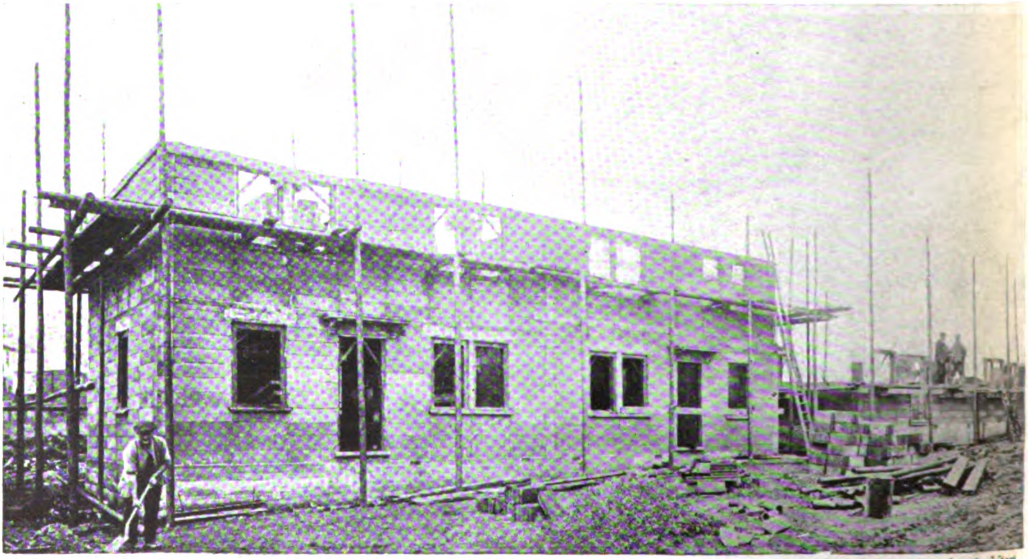
The blocks are manufactured by plant specially designed for making the large "Winget" concrete blocks and slabs, and which can be adapted to make any concrete block and slab within the limits of 36 in. by 12 in. by 9 in. These machines are being used on the Birmingham housing scheme as well as at Wakefield, and have an approximate output of 80 to 100 slabs an hour. A complete unit can turn out enough blocks and slabs for the erection of houses of the Wakefield type at the rate of one house a day. The slabs can be made on the site entirely with unskilled labour, and the maximum proportion of unskilled and semi-skilled men can be employed in the erection of the houses themselves.

The total cost of the Wakefield houses, including electric light, paths, drains, etc., is :—

	Superficial Area.	
Type 3A.	756 sq. ft. . .	£378
Type 1A.	864 ,, . .	415
Type B.	948 ,, . .	474

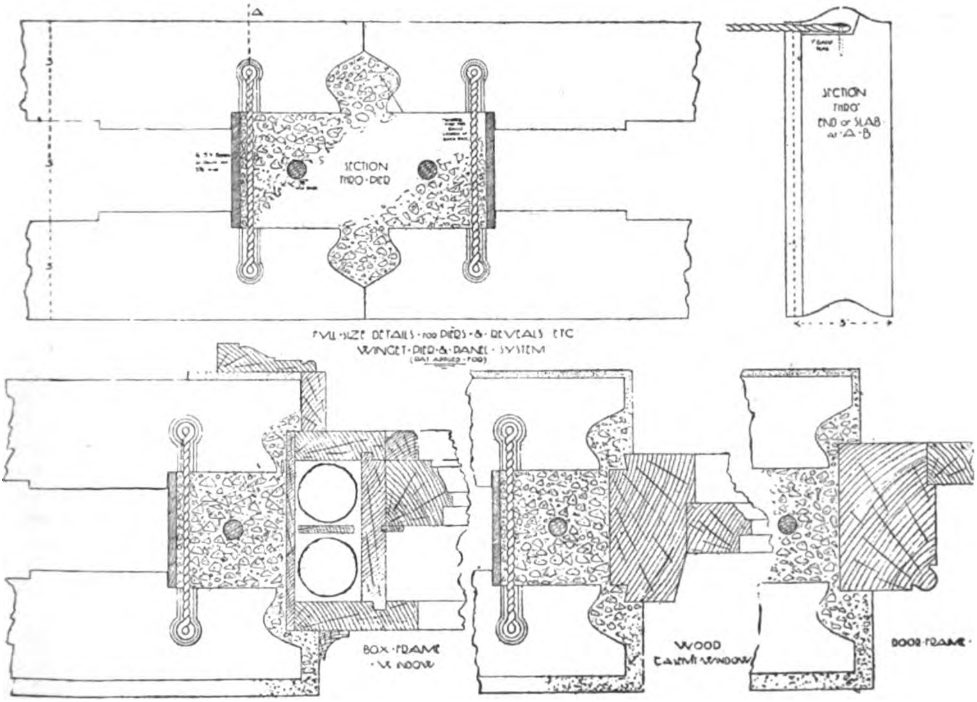
The houses are being built on the "pier and panel" system, one of the distinctive features of which is that shuttering is entirely dispensed with. The ends of the concrete slabs are so formed that the piers are formed *in situ* as the walls go up. The concrete slabs are shaped on bed joints to ensure rigidity and proper alignment during erection. In addition, the top, or male, edge of each slab has two shallow recesses to receive the looped ends of the twisted galvanised wire ties. The ends of the slabs are shaped and rebated to receive "pugging strips," i.e. strips of cement asbestos sheeting or compo board, $3\frac{3}{8}$ in. wide.

The slabs are laid dry, and as each course is laid (or two or three courses, whichever may be most convenient) the pier space between the "pugging strips"



[Mr. Percy Morris, Architect.

WAKEFIELD HOUSING SCHEME : FIVE DAYS' PROGRESS ON PAIR OF HOUSES.


A
SECTION THRO' PIER
SECTION THRO' END OF SLAB AT A-B
5"
FULL SIZE DETAILS FOR PIERS & REVEALS ETC
WINGET PIER & PANEL SYSTEM
(PAT APPLIED FOR)
BOX FRAME WINDOW
WOOD CASEMENT WINDOW
DOOR FRAME

Wakefield Housing Scheme: Details of Construction.

is filled in with wet concrete, and, if desired, reinforced.

The ends of the slabs are so shaped that when this concrete is set they are firmly—and permanently—tied to the piers by strong locking joints.

The twisted wire ties and galvanised nails which hold the slabs in position primarily, and during course of erection, become embedded in the wet concrete of the piers, and thus increase the bond. The " pugging strips " of asbestos cement sheeting, or other suitable thin material, obviate the use of timber shuttering, while door and window-frames fit in the shaped ends of the slabs and act as centering where they are required.

A feature of the slabs is the " lamb's tongue " joint of the top and bottom edges. This is of a gentle sweep, giving no unduly sharp or projecting portions likely to be broken off during manufacture or during seasoning or building. Thus, when the slabs are superimposed dry upon one another they convey an interlocking strength from one slab to the other. Proper alignment is also ensured without undue trouble. Another advantage is that the number of standardized units has been reduced to four, namely (1) 36 in. by 9 in. by 3 in. slabs for the outer walls, (2) quoins, (3) three-way or " T " blocks, and (4) 18 in. by 9 in. by 4 in, " Drylaid " blocks for the internal and partition walls. At the first or succeeding floor heights, and at roof height, 3-in. courses of *in situ* concrete are run in with suitable reinforcement right round the building, the reinforcement being looped and engaged with the reinforcing rods at each corner of the building. These 3-in. courses not only act as wall plates and serve to carry floor joists, roof and ceiling spars, but also tie the whole structure together laterally. Steps, heads, sills, mullions, etc., may be pre-cast or formed *in situ* as erection proceeds.

The houses at Wakefield are being erected by Messrs. George Crook & Sons, Ltd., of Wakefield.

CONCRETE SURFACED ROADS.

THE following interesting article on concrete road surfaces, by Major R. A. B. Smith, A.C.G.I., A.M.Inst.C.E., appeared in a recent issue of *The Surveyor* :—

Amongst the conclusions reached by the International Road Congress on the subject of concrete road surfaces appear the following words :—

(*a*) When cracks occur they are unsightly.

The writer has been in the position to study these questions, and feels that the following remarks based on his personal observation may be useful to many engineers, and show the way to still further progress.

CONTINUOUS CONSTRUCTION.

There are three methods of construction advocated to-day; the first of which I propose to examine is that of continuous construction. The argument in favour of this form of construction is that, by suitably reinforcing, the number of serious cracks which form is negligible. Nevertheless, they do occur, and it is not an easy matter to deal with them, and when a road bursts it is, of course, far more serious. In the case of Liverpool, a long length of concrete road has been laid, the system of construction is continuous, there is no reinforcement, and there were, when last visited, no unsightly cracks, but at one of two of the joints at the end of a day's work the concrete had parted straight across the road. In seeking for a reason for the almost complete absence of cracks in this case two features presented themselves—namely, the fact that the aggregate used in the concrete is well-burnt clinker, and also that Liverpool does not receive quite the same extremes of heat met with in the south of England nor the frosts of Scotland. Whether clinker concrete behaves better under temperature effects has not yet been proved to the writer's satisfaction, but it is certainly worth investigating.

At Bradford, there is, I believe, another example of a crackless concrete road constructed on the continuous principle ; in this case the concrete is reinforced at both top and bottom, which would appear a good argument for double reinforcement were it not that Liverpool is equally successful with no reinforcement and the temperature effects in both places must be very similar, though by using double reinforcement the depth of concrete required should be less.

At Southwark, a borough of London, continuous construction has been very successful, and the conclusion to which we would seem to arrive is that when the road is well protected by buildings from extremes of heat and cold this method is satisfactory, but not generally for exposed positions.

ALTERNATE BAY CONSTRUCTION.

The next method which is largely adopted is known as the alternate bay construction.

This method has been successfully carried out by Mr. Robinson, the County Surveyor of Surrey. It is, of course, not right to examine its virtues on one success, and it is only right to say that Mr. Robinson pays great attention to obtaining a very well graded aggregate and also to the quantity of water employed ; there is no doubt that excess of water has led to many unnecessary cracks in the past. The advantage of this form of construction is that a crackless road can be obtained ; the disadvantages are that one has a rather more laborious and more expensive method, and that during the after period there are joints at intervals of 14 ft. which will almost certainly require slight attention. This takes the shape of running a band of bitumen over the joint annually, in order to prevent abrasion. A careful study of the joints of alternate bay constructed roads after they have taken considerable traffic will show that there is a gradual displacement of the pieces of coarse aggregate at the joints, and that, therefore, this treatment with bitumen is very necessary. At Manchester this type of construction is giving every satisfaction, but, again, we find ourselves in a district where the climate is equable and where the continuous form of construction has proved equally as satisfactory.

EXPANSION JOINTS.

The third form of construction to be examined is the use of expansion joints. The advantage of this form of construction is that it has the merits of continuous construction inasmuch as the work is straight ahead, and also a crackless road can be obtained. The question arises as to how far apart these joints should be placed, and it would appear that 60 ft. apart is correct for roads of a width not exceeding 24 ft., and about 50 ft. for roads from 24 to 30 ft. wide. For greater widths than 30 ft. the alternate bay construction seems equally advantageous. The disadvantage is that there is an undoubted joint which must be kept in order, and it will be necessary to see that it is properly filled annually.

By giving the arrises a radius of from ¼ in. to ½ in. the risk of abrasion is considerably reduced and a slight difference of level between the two abutting concretes is not a cause of abrasion, but when this difference is great the joint is not likely to be successful. At Bristol the expansion joint system was found superior to continuous construction, and also on the new Cambridge road.

To summarise our observations it would appear that :—

(1) Continuous construction is generally satisfactory in sheltered positions, and in a very equable climate.

(2) Alternate bay construction is satisfactory for roads of great width.

(3) The expansion joint method is satisfactory in exposed positions on roads up to 30 ft. wide.

QUESTIONS AND ANSWERS RELATING TO REINFORCED CONCRETE.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.*—Ed.**

GLASS MOULDS.

Question.—I wish to make concrete products with a marble-like surface by using plate-glass moulds, but do not know where such moulds can be obtained. How am I to cast a product 18 in. long by 5 in. wide by 3 in. deep with splays on each of the top edges ?—B.T.

Answer.—Plate glass is often used in the bottom of a mould to get a good finish on one face of a concrete product, but it is doubtful if it would be advisable to use a mould made entirely of glass with a hinged top on account of the risk of breakage. No doubt any glass manufacturer would supply such a mould, but it would probably be better, if the same finish is required on all faces, to make a wooden mould of the shape desired and line the bottom, splays, sides, and ends with separate pieces of plate glass and after filling the mould press a piece of plate glass on to the top. Separate pieces of glass used in this way would be much cheaper than having a complete glass mould with a hinged top specially made, and the pieces would be easy to replace if they got broken. The wooden mould would, of course, have to be made slightly larger than the product required to allow for the thickness of the plate glass. Perhaps some of our readers who have had experience with this class of work would give our querist the benefit of their experience.

Live Load = 75 lbs. sq. ft.

$M = wl^2/10$

$l = 10{\cdot}25\sqrt[4]{d^3/w}$

$D = 1/8"$

TABLE. I.

MAXIMUM SPAN OF FLOOR SHEATHING FOR VARIOUS THICKNESSES OF SLAB

Thickness of Slab	Thickness of Sheathing			
	1"	1¼"	1½"	2"
3"	32½ ins.	39½ ins.	46 ins.	59 ins.
4"	31½	38	45	57½
5"	31	37½	44	56
6"	30	36½	43	55
7"	29½	36	42	54
8"	29	35	41½	53
9"	28½	34½	41	52
10"	28	34	40	51½
11"	27½	33½	39½	50½
12"	27	33	39	50

DESIGN OF FORMWORK FOR REINFORCED CONCRETE CONSTRUCTION. (*See p.* 789.)

DESIGN OF FORMWORK FOR REINFORCED CONCRETE CONSTRUCTION.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

IV.—DESIGN TABLES

Table 1—Slab Sheathing

In designing sheathing for slabs it will be found that deflection and not strength in bending or shear will govern the thickness. The table is calculated from formula 15, assuming a live load of 75 lbs. per sq. ft.

The timber is assumed to be dressed $\frac{3}{16}$ in. The sheathing is calculated for continuous spans; for single spans deduct one-eighth from the spans given in the table.

One-inch sheathing is the size most ordinarily used for floor slabs. To use the sheathing to the best advantage the joists should be spaced at the maximum span of the sheathing, to which may be added the thickness of the joist, but if this means using an extra heavy joist the spacing will be governed by the strength of the joist.

Table 2—Wall Sheathing

In this Table strength in bending governs the maximum spans. This is because the loads are heavier and the spans shorter than for slabs.

For walls up to 10 ft. high the weight of the equivalent fluid causing horizontal pressure is taken as 125 lbs. per cu. ft., for walls 10 ft. to 20 ft. high as 100 lbs. per cu. ft., and for walls higher than 20 ft. as 75 lbs. per cu. ft.

The Table is calculated from formula 46, and the deflection will be less than $\frac{1}{8}$ in. by formula 47.

It is usually possible to use wall sheathing at its maximum span, this being calculated at the bottom of the wall, and so studs should be spaced at the spans given in the table, to which may be added the thickness of the stud.

One-inch or $1\frac{1}{2}$ in. sheathing is usually used for walls.

Table 3—Column Sheathing

As for wall sheathing, strength in bending will govern the span.

The pressure is assumed to be constant between yokes, with intensity equal to that at the lower yoke, and the formula for calculating the sheathing will be the same as for wall sheathing, "w" being taken at 125 for all heights.

The spans will be the same as for wall sheathing for heights up to 10 ft., but for greater heights the spans will be less. Deflection will be less than $\frac{1}{8}$ in.

For small-size columns the maximum span of the sheathing will govern the spacing of the yokes.

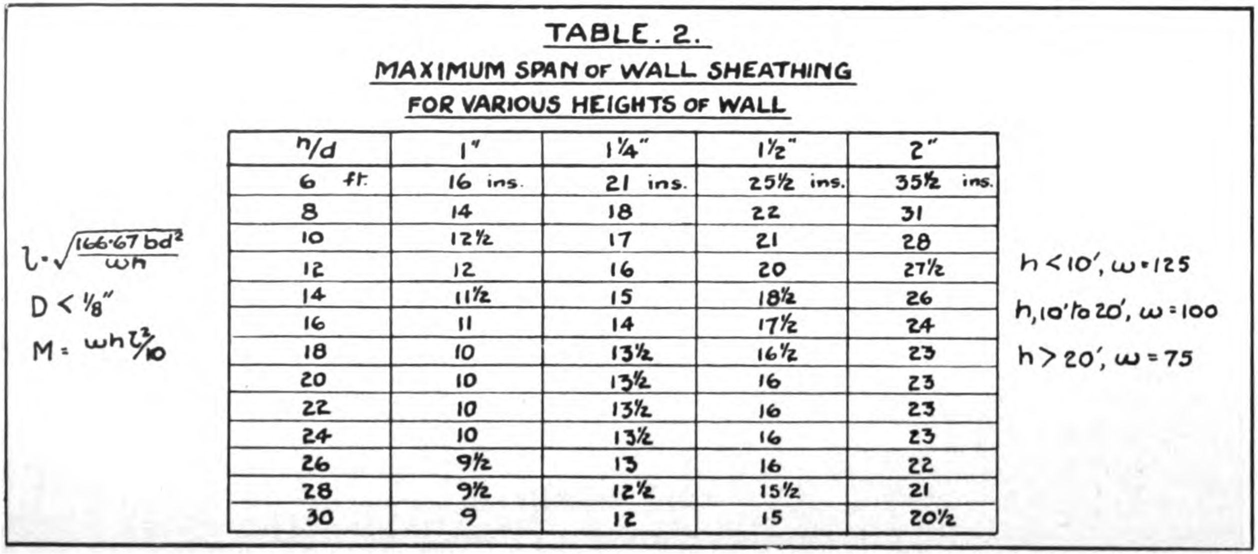


TABLE. 2.

MAXIMUM SPAN OF WALL SHEATHING FOR VARIOUS HEIGHTS OF WALL

$l = \sqrt{\frac{166 \cdot 67\, bd^2}{wh}}$

$D < 1/8''$

$M = whl^2/10$

h/d	1"	1¼"	1½"	2"
6 ft.	16 ins.	21 ins.	25½ ins.	35½ ins.
8	14	18	22	31
10	12½	17	21	28
12	12	16	20	27½
14	11½	15	18½	26
16	11	14	17½	24
18	10	13½	16½	23
20	10	13½	16	23
22	10	13½	16	23
24	10	13½	16	23
26	9½	13	16	22
28	9½	12½	15½	21
30	9	12	15	20½

$h < 10', w = 125$

$h, 10' \text{ to } 20', w = 100$

$h > 20', w = 75$

DESIGN OF FORMWORK FOR REINFORCED CONCRETE CONSTRUCTION.

TABLE. 3.

MAXIMUM SPAN OF COLUMN SHEATHING

FOR VARIOUS HEIGHTS OF COLUMN

$l = \sqrt{\frac{166{\cdot}67 bd^2}{wh}}$

$D < 1/8"$

$M = wh l^2/10$

h/d	1"	1¼"	1½"	2"
6 ft.	16 ins.	21 ins.	25½ ins.	33½ ins.
8	14	18	22	31
10	12½	16	20	27½
12	11	14½	18	25
14	10½	13½	17	23
16	9½	12½	15½	21½
18	9	12	15	20½
20	8½	11½	14	19½
22	8	11	13½	18½
24	8	10½	13	17½
26	7½	10	12½	17
28	7½	9½	12	16½
30	7	9	11½	16

$w = 125$

DESIGN OF FORMWORK FOR REINFORCED CONCRETE CONSTRUCTION.

TABLE. 4.

MAXIMUM SPACING OF FLOOR JOISTS FOR VARIOUS SPANS AND THICKNESSES OF SLAB

Slab Thickness	Size of Joist	Span of Joist in feet										
		3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
3"	2"×4"	39 ins.	29 ins.	22 ins.	17 ins.	14 ins.	12 ins.	10 ins.	ins.	ins.	ins.	ins.
	2"×6"				41	33	27	23	19	17	14	13
4"	2"×4"	35	26	20	16	12	10					
	2"×6"				37	30	25	20	17	15	13	11
5"	2"×4"	32	23	18	14	11	9					
	2"×6"				33	27	22	19	16	14	12	10
	2"×8"							34	29	25	22	19
	3"×4"			28	22	18	15	12	10			
	3"×6"									40	35	30
6"	2"×4"	30	22	16	13	10						
	2"×6"			39	31	25	21	17	15	12		
	2"×8"						37	31	27	23	20	17
	3"×4"		34	26	20	17	14	11	10			
	3"×6"					39	32	27	23	20	17	18
7"	2"×4"	27	20	15	12	10						
	2"×6"			36	29	23	19	16	13	11		
	2"×8"						35	29	25	21	19	16
	3"×4"		31	24	19	15	13	10				
	3"×6"					36	30	25	21	18	16	14
8"	2"×4"			14	11							
	2"×6"			33	26	21	18	15	12	11		
	2"×8"					39	38	27	23	20	17	18
	3"×4"			22	18	14	12	10				
	3"×6"					34	28	23	20	17	15	13
	3"×8"								[illegible]	[illegible]	[illegible]	[illegible]

lbs.sf.; to right of heavy line D < 1/8" with live load of 40 lbs.sf.

$\frac{wl^2}{10}$ add 25% to spacing.

	2"×8"	39	32	27	23	20	17	15	13			
	2"×10"			40	34	29	25	22	20	18	16	14
	3"×4"	13										
	3"×6"	31	26	22	18	16	14	12	11	9		
	3"×8"			40	34	29	25	22	20	17	16	14
	3"×10"							35	31	29	26	23
10"	2"×6"	19	15	13	11	9						
	2"×8"	34	28	24	20	17	15	13	12	10		
	2"×10"			38	32	28	24	21	19	17	15	13
	3"×6"	29	24	20	17	15	13	11	10			
	3"×8"			37	32	27	24	21	18	16	15	13
	3"×10"						38	33	31	27	25	21
	4"×6"	40	33	28	24	20	18	16	14	12	11	10
	4"×8"					37	32	28	25	22	20	18
11"	2"×6"	18	14	12	10							
	2"×8"	32	26	22	19	16	14	12	11	10		
	2"×10"			35	30	26	23	20	17	15	14	12
	3"×6"	28	23	19	16	14	12	11	9			
	3"×8"			35	30	26	23	20	17	15	14	12
	3"×10"						36	31	28	25	22	20
	4"×6"	38	31	26	22	19	17	15	13	11	10	
	4"×8"					35	30	27	24	21	19	17
	4"×10"								38	34	32	29
12"	2"×6"	17	14	11								
	2"×8"	30	25	21	18	15	13	12	10			
	2"×10"		40	33	28	24	21	19	16	15	13	12
	3"×6"	26	22	18	15	13	11	10				
	3"×8"		40	33	28	24	21	19	16	15	13	12
	3"×10"					39	34	29	26	23	21	19
	4"×6"	36	30	25	21	18	16	14	12	11	10	
	4"×8"				39	33	29	25	22	20	18	16
	4"×10"								36	32	29	26

$S = \frac{1600\,bd^2}{wl^2}$ $l = 2{\cdot}04\sqrt{d}$ $M = \frac{wl^2}{8}$, f

Figures to left of heavy line give D < 1/8" with live load of

ONSTRUCTION: MAXIMUM SPACING OF FLOOR JOISTS.

One-inch and 1¼ in. are the thicknesses usually used, the latter when the forms are to be used several times over. Timber is assumed to be dressed $\frac{3}{16}$ in.

Table 4—Joists

This Table is calculated from formulæ 5 and 12, assuming single spans, which is the usual condition in beam and girder construction. When the joists have one or more centre supports, 25 per cent. may be added to the spacings in the table, using a span equal to the distance between supports.

Spacings to the left of the heavy line will give a deflection less than ⅛ in. with a live load of 75 lbs. per sq. ft., and to the right of the heavy line the spacings will give a deflection less than ⅛ in. with a live load of 40 lbs. per sq. ft.

Unless heavy construction loads are likely to be placed on the slab before it has set the latter values may be used.

It will be noticed that the maximum span for deflection depends only on the depth and not the width of the joist.

For maximum economy of material choose joists that can be spaced at the maximum span of the sheathing; this, however, will not always give the cheapest design, since the larger-size joists will cost more than the smaller for the same volume of timber, and it is often cheaper to use smaller joists spaced closer together than required by the strength of the sheathing.

Spacing for shear is calculated by formula 9; it will always be greater than that allowable for bending if the full size of joist is used. If, however, the depth of the joist is decreased at the support, as is sometimes necessary for curved slabs and arch rings, then the unit shearing stress should be investigated.

The thickness of the ledger carrying the joists on the beam side is given by formula 23; it will vary from 1 in. to 2 ins., and this will govern the size of the ledger that is nailed on to the beam side.

All joists are assumed to be dressed ¼ in. on each dimension. For undressed timber of full size, multiply the spacings given by the following factors:—

For 2 in. by 4 in.	joists multiply by	1·3
2 in. by 6 in.	.. ..	1·25
2 in. by 8 in.	.. ..	1·20
2 in. by 10 in.	.. ..	1 20
3 in. by 4 in.	.. ..	1·25
3 in. by 6 in.	.. ..	1·20
3 in. by 8 in.	.. ..	1·15
3 in. by 10 in.	.. ..	1·15
4 in. by 6 in.	.. ..	1·15
4 in. by 8 in.	.. ..	1·15
4 in. by 10 in.	.. ..	1·125

The commonest size used for joists is 2 in. by 6 in.

(*To be continued.*)

NEW METHOD OF CONCRETE CONSTRUCTION.

A FORM of half-timber concrete walling, which seems to have considerable possibilities for rapid construction and surface finish, has been patented by Messrs. John Wallis & Co., of Troy Mills, West Hyde, Rickmansworth. The system is one of pre-cast units, which may be made either in a factory or on the site. Usually the units are of the full height of the stories of the building, but they may be of any required height up to about 8 or 9 ft. to suit the design of the building. In making the units the timber which is to show on the outside of the wall is used as the shuttering in which the concrete is cast, and therefore a sound weather-resisting timber, such as oak, is used for this purpose. This framing is made of timber of a minimum size of 3 in. by 4 in., jointed together by mortice and tenon and pinned with oak pins. The outer edges of the frame are lap-rebated so that they may be jointed together when in position. These frames are laid on a prepared base on the ground and filled with concrete not less than 3 in. thick. An attractive surface is formed by pressing flints or other stones into the concrete, or if desired, the panels may be cast face-down by first placing a layer of flint, pea-shingle, or other suitable stone in the bottom of the mould and then filling in the backing of concrete. If it is desired to form smaller panels, timber frames are put in across the frame as shown in *Fig.* 2.

In the erection of a building the ground floor frames are bedded on the concrete or brick plinth with a dampcourse, the underside of the frame being grooved or holed so that the dampcourse is squeezed up and keys or dowels the frame in position. The vertical lap-rebated joints between the frames are treated with a bituminous composition and nailed, screwed or bolted together.

When the building is of more than one story the ends of floor joists are usually trimmed and weathered with an oak stringcourse bedded in a bituminous composition along the outer edge of the ground floor frames and level with the top of floor joists; concrete is filled in between the joists and the inside face of the frames, and the upper frames bedded on in bitumen and bolted down to the ground floor

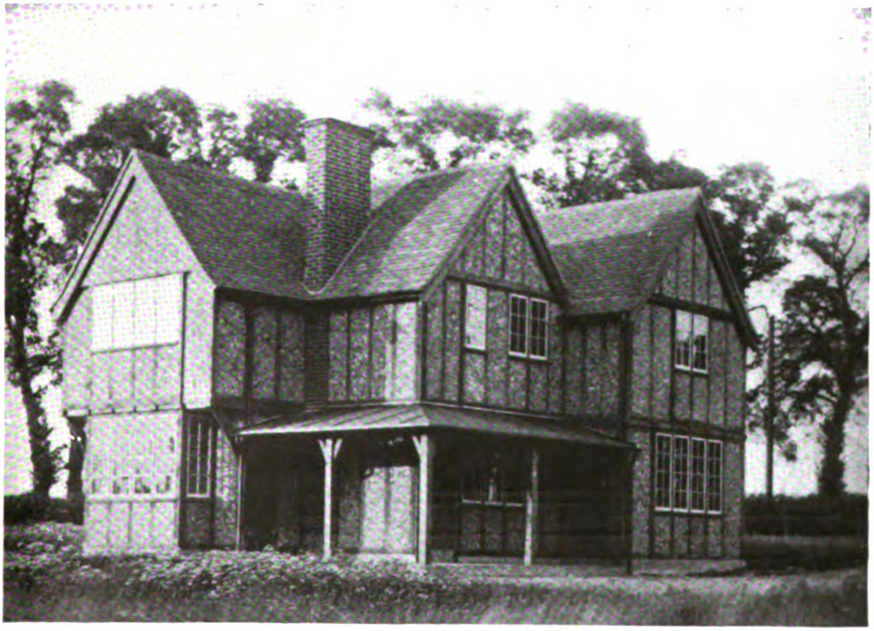


FIG. 1.—HOUSE IN BUCKINGHAMSHIRE BUILT ON HALF-TIMBER CONCRETE SYSTEM.

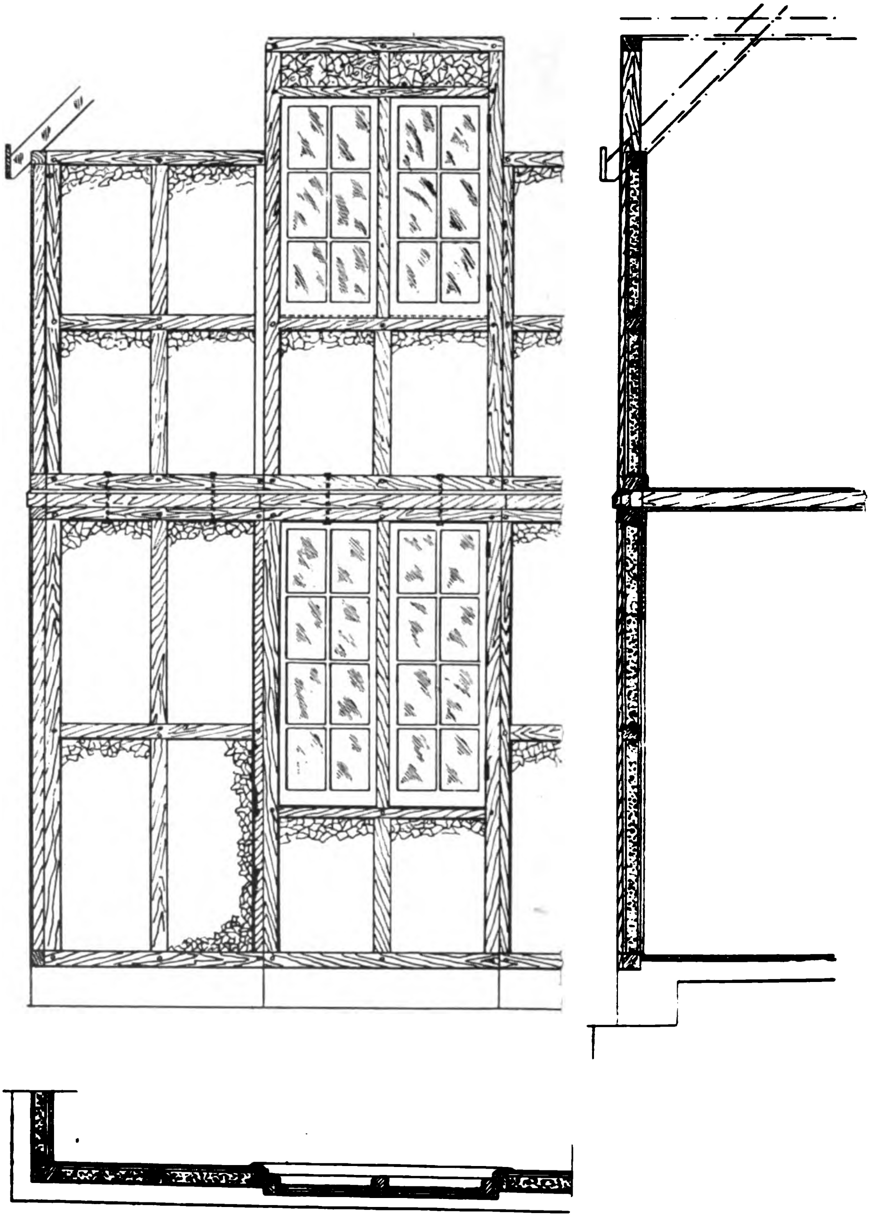


FIG. 2.—ELEVATION, SECTION, AND PLAN OF HALF-TIMBER CONCRETE CONSTRUCTION.

frames. If desired, the upper floors can be projected from the face of the lower floor.

To meet the requirements of the Ministry of Health for a cavity wall, a cavity is formed between the back of the concrete panels and the finished lining of the room, such as plastering, wallboarding, etc., either by fixing battens to the oak framing or by having the oak framing thick enough to project beyond the back of the concrete panels to receive the inner lining. We are informed that without a cavity walls built on this system with framing 4 in. thick and concrete panels 3 in. thick have formed perfectly weatherproof houses without any signs of condensation. For garages and suchlike buildings oak frames 3 in. thick and concrete 2½ in. thick are sufficient to provide a weatherproof structure.

The following advantages are claimed for this system: Walls can be rapidly erected and buildings roofed in, when they quickly dry out and become rapidly ready for occupation. The framed units are ready for erection three days after the concrete has been placed in them. It can compete in cost with other materials in any district, especially where the units are made on the site and where suitable materials for making concrete are available. Owing to the thinness of the walls, there is a saving of about a foot in the length and breadth of a building compared with 11 in. brickwork. If the framework is treated with oil no painting is required, and the cost of upkeep is negligible.

A good many houses, both large and small, have already been built on this system, and, as is shown by *Fig.* 1, some charming effects are possible by the careful selection of the facing material and attention to the design.

AN ITALIAN FLOATING DOCK.

THE first floating dock constructed of reinforced concrete in Italy has recently been launched at Trieste. It was designed for use in the Adriatic, and its principal dimensions are: Total length, 214 ft.; length above water, 174 ft.; inside width, 50 ft.; total width, 70 ft.; inside height, 35 ft.; total height, 57 ft.

The details of reinforcement are in accordance with usual standards. Attention may be called to the use of a well-trowelled 1 : 3 cement mortar, rather more than ½ in. thick, being regarded as sufficiently impermeable to water. For the construction, 320 tons of Portland cement, 1,280 cu. yds. of aggregate and 200 tons of mild steel reinforcement were employed. The total weight of the structure, including plant and machinery, is about 1,700 tons.—*Il Cemento.*

THE FOREMAN'S GUIDE TO CONCRETE.—III.

A MANUAL FOR ALL ENGAGED IN CARRYING OUT CONCRETE AND REINFORCED CONCRETE STRUCTURES.

By ALBERT LAKEMAN, M.S.A., M.I.Struct.E.

STEEL.

THE strength and safe working stress on the concrete has been dealt with and the question of the steel used for reinforcement can be considered. This material is not manufactured on the site and the quality is therefore not in the hands of the foreman, but its preparation and placing in the work are of vital importance, and it is possible to reduce the strength of the finished work in a very serious manner if the drawings are not rigidly adhered to. As previously mentioned, the steel rods are introduced in the concrete to provide the necessary resistance to tension, as concrete is deficient in this resistance. In all reinforced concrete calculations the value of concrete in tension is neglected entirely, and no allowance whatever is made for its resistance. Actually concrete has a small resistance to tension, but theoretically it is taken as nothing because it cannot satisfactorily act alone and when used with steel it will crack and become useless to resist any appreciable load before the reinforcement has been called upon to put forward even a small proportion of its resistance.

The safe working stress on ordinary mild steel in tension is taken at 16,000 lbs. per sq. in., and as this provides for a factor of safety of 4 the ultimate strength should be about 64,000 lbs. per sq. in. It will be seen that this is a very high figure compared with the values given for the working stress on concrete in compression and it explains why the amount of steel required is so small compared with the bulk of the concrete.

Steel reinforcement is also used to increase the resistance to compression where the amount of concrete that can be conveniently used is limited, as in the case of a small beam to carry a heavy load, or in the case of columns or piers. The resistance to compression offered by steel is the same as that in tension, or, in other words, it requires the same weight to crush it as it does to tear it, and this fact has rendered steel a very valuable material for building purposes apart from any other consideration.

When steel is used in conjunction with concrete to resist compression, however, the working stress is limited to a value which has some relation to the stress on the concrete, as will be explained later when dealing with elasticity. The quality of the steel can be tested in various ways, but this branch of the work will not be dealt with by the foreman on the site, who can consider the material delivered to him for use on the job as reliable and up to the requirements of the designer as regards strength. It remains with the foreman, however, to see that the steel is correctly used in order that it may be able to develop its resistance effectively in the finished work as a part of the complete material, which is reinforced concrete.

COMBINATION OF CONCRETE AND STEEL.

The two parts of reinforced concrete have, up to the present, only been dealt with separately, but the combination of these two must now be considered as it is in this form that they are of real importance in building work.

Owing to its comparatively great strength the amount of steel required to reinforce concrete is very small, and as steel is an expensive material the designer must be economical in its use and only provide for the minimum amount actually required if full advantage is to be taken of the possibilities of this form of construction.

In an ordinary simple reinforced concrete beam the amount of steel required to give the necessary resistance to tension will only be 0·675 per cent. of the amount of concrete required to give the necessary resistance to compression and provide protection for the steel. That is to say, if the area in section of the concrete beam is 100 sq. in., then the area in section of the steel rods will only be 0·675 sq. in.; or, again, one square inch of steel is sufficient to reinforce 148 sq. in. of concrete. It will be seen therefore that the steel will always be in comparatively small quantities and the correct placing is of the utmost importance.

As a simple example of the necessity for working accurately to the drawings, assume that a beam is 14 in. deep by 10 in. wide and the reinforcement specified is given as three ⅝-in. diameter rods, which are equal to about 0·675 per cent. of the concrete. If one of these rods is accidentally left out the strength of the beam will be reduced to two-thirds of that provided for by the designer, and if the beam is constructed to carry part of a warehouse where the weight of the slab is 75 lbs. per ft. super and the superimposed load 225 lbs. per ft. super, making a total of 300 lbs. in all, this load must be reduced by one-third if the beam is not to be overstressed. The safe total load, therefore, is reduced to 200 lbs., and as the weight of the slab will still be 75 lbs. per sq. ft. the safe superimposed load will only be 200 minus 75, or 125 lbs. per ft. super.

It will readily be seen that this is a serious reduction in the strength, and while it is extremely unlikely that any reliable foreman will execute work without seeing that all the rods are placed in position, the same principle as regards loss of strength if the reinforcement is not put in according to the drawings will apply to all parts of a reinforced concrete structure, and this example is given for the purpose of simple explanation.

There are many cases where the amount of the reinforcement used is somewhat over 0·675 per cent. of the concrete, and in some instances it may be nearer 1·00 per cent., but the quantity of steel is still very small compared with the concrete, and the best design is obviously one in which the amount of reinforcement provided is the minimum that is theoretically necessary to resist the stresses.

It was previously mentioned that in an ordinary simple reinforced concrete beam the necessary amount of steel to provide for tension is only 0·675 per cent. of the amount of concrete necessary to provide for compression, and it is necessary to explain that the compression stress and the tension stress will be equal to each other when a beam is subjected to a bending moment and the ratio of the steel to the concrete is affected by the strength and arrangement of the materials and not by any difference in the amount of the stress that has to be provided for. As the compression stress and tension stress, as mentioned above, are equal, the *resistance* to compression and tension must also be equal, because an excess of strength in either material will be wasted, as the excess cannot be developed and advantage taken from it before the weaker of the two resistances has been overcome by the load.

ELASTICITY.

Before proceeding to deal further with the combination of concrete and steel it is advisable to give some explanation and notes on the elasticity of the materials. The term elasticity as used in construction design is somewhat difficult to explain in simple language, but it will be sufficient if the reader can gather the general principles and reason for considering this aspect of the subject. Elasticity does not mean merely the amount by which a material can be stretched, but rather its power to return to its original shape after it has been distorted by the application of a load or force. If a piece of rubber is pulled or squeezed it will quickly return to its original shape after it is released, because its elasticity is good, whereas a piece of 4-lbs. sheet lead if stretched or squeezed will not return to its original shape because its elasticity is bad. The power to regain its original shape after the removal of the stress varies considerably in different materials, and when a material is distorted by a force and does not regain its shape after the removal of that force it is said to have a "permanent set," or, in other words, it has become "set" into a new shape.

It is possible to produce a permanent set in any material if sufficient stress is caused on it by the application of a load which is approaching the ultimate load, but there is a safe stress for each material which will only cause distortion until the load is removed. Each material therefore has a limit to its elasticity known as the "elastic limit," this being the maximum stress per square inch that can be applied to it without causing any appreciable permanent set. After the elastic limit has been reached the material begins to yield and its behaviour will be uncertain, and for this reason the real factor of safety is the ratio between the working stress and the elastic limit rather than between the working stress and the ultimate strength, as was mentioned previously.

Thus in the case of ordinary mild steel the elastic limit will be approximately only about one-half the ultimate strength, or about twice the ordinary working stress; the real factor of safety in steel-frame buildings and reinforced concrete structures is therefore only about 2, because if the actual load is more than twice the specified working load the steel is likely to become permanently distorted, and once it commences to yield it cannot be considered reliable.

It will be easily realised that the elasticity of concrete and steel are very different, and the elastic limit of the former is much less than the latter. Generally speaking, the elasticity of steel is fifteen times more than concrete, and this is a very important point because when these two materials are designed to act together allowance must be made for this difference.

As an example, if we consider a concrete column which is reinforced with four vertical steel rods (as indicated in *Fig.* 17) and assume that this is loaded in such a manner that the materials are compressed and *shortened* by, say, one inch, it is necessary, if the materials are to continue to act together, that both concrete and steel are shortened by the same amount, because if not the whole load will be taken by the one material. If it takes fifteen times as much stress to shorten the steel as it does the concrete the working stress on the steel must be taken as fifteen times the working stress on the concrete.

The working stress on the concrete, as previously mentioned, is taken at 600 lbs. per sq. in. and the stress on the steel allowed for must therefore not exceed 600 x 15, which equals 9,000 lbs. per sq. in. Mild steel will safely resist 16,000 lbs. per sq. in. in compression but it was mentioned previously that when used in conjunction with concrete the value was limited by the relation of the two materials, and this point is the one that was referred to. If, for example, the stress on the steel is considered as 16,000 per sq. in. in the column shown in *Fig.* 17, then the working stress on the steel will be more than fifteen times the working stress on the concrete, and if this is the case the steel will be shortened under the load more than the concrete and we should get a condition as indicated in *Fig.* 18, which is obviously impossible because the steel rods are below the surface and thus could not be in contact with the load at all. The stress of 16,000 lbs. per sq. in. on the steel could not therefore be reached before the safe load on the concrete had been exceeded.

Again it is necessary to maintain the ratio of fifteen in dealing with the design because a value of less stress on the steel than fifteen times that on the concrete

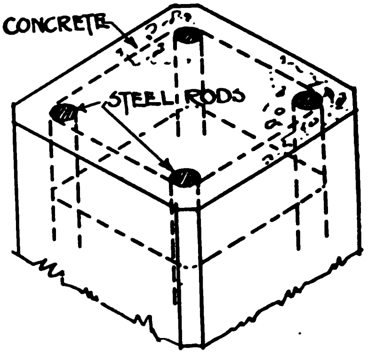


FIG. 17.

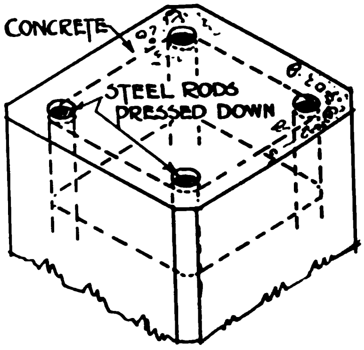


FIG 18

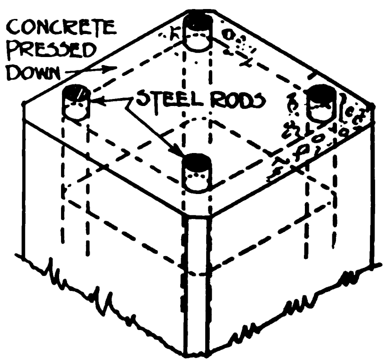


FIG. 19.

means the latter would be shortened more than the rods and the latter must project above the surface, as shown in *Fig.* 19, which is obviously absurd if the load is bearing on the whole area of the column.

These illustrations are given to show how the two materials must be designed to act together unless the value of the concrete is neglected and the steel is provided in sufficient quantity to take the whole of the load, which is clearly not economical. Where the value of the concrete in compression is neglected, as in some special cases of double reinforced beams, it means that theoretically the concrete can fail under the load, but the strength of the beam will not be affected.

The ratio of the measure of elasticity given as 15 is the one usually applied in calculations, but if concrete of special mix is employed this ratio may be varied.

These notes on elasticity must not be considered as covering the whole subject in a comprehensive and strictly technical manner, but they are presented with the idea of giving the reader a general knowledge of a subject upon which much might be written.

SHEARING RESISTANCE.

The working stresses for concrete and steel in compression and tension have been given, but no value has yet been stated in connection with resistance to shear. The Regulations of the L.C.C. state that the value of the shearing stress in concrete shall not exceed one-tenth of the working stress for compression, and as the latter was given as generally being 600 lbs. per sq. in. it follows that the working stress for shear in concrete generally is 60 lbs. per sq. in.

In many single-reinforced concrete beams the amount of concrete provided is sufficient to give the necessary resistance to shear without any steel being required theoretically, but in designing it is usual to utilise some of the rods near the supports as shear-resisting members. The shearing tendency is always at the maximum near the supports, and in the case of a uniformly distributed load the tendency gradually diminishes toward the centre of the span, where it is nil. This accounts for the stirrups or shear resisting members being placed closer together near the supports than at the centre of a beam, and also for the bending upwards of some of the main steel rods. This latter point, however, requires further explanation, which will be given later.

The working stress for ordinary mild steel in shear is limited to 12,000 lbs. per sq. in., and the question of elasticity does not affect the acting of the two materials together because the action is a sliding one, and where the steel passes through the concrete the latter cannot slide, as mentioned in the description of shear, without the steel rods being also cut by the action. The steel rods will act in a similar manner to the dowels mentioned in connection with *Fig.* 9, and when vertical steel stirrups are employed these would act in a similar manner to bolts passed through the planks shown in *Figs.* 11 and 12, as the planks could not slide on one another unless the bolts were cut through by the horizontal shear. The question of the variation in the shearing stress and the provision of the necessary resistance can be further considered when dealing with the reinforcement for beams.

ADHESION.

The adhesion, or grip, between the concrete and the steel rods is obviously of great importance, as the two materials are acting together and should the adhesion fail the steel rods will slip through the concrete and the necessary resistance cannot be developed. The concrete adheres or sticks to the steel reinforcement and holds the latter in position while the resistance is being developed, and the bond between the two materials must be sufficient to withstand the tendency to separate which will be present when the steel is being stretched by tension or crushed by compression.

The allowance made for adhesion when designing is 100 lbs. per sq. in. of the surface of the steel in contact with the concrete, provided the ends of the rods are hooked or otherwise properly anchored into the concrete. The area of the steel which is in contact will depend on the diameter and length of the rod, and this has led to the simple rule, obtained by calculation, that a rod must have a grip length of at least forty times its diameter, when the end is hooked, if the resistance of 16,000 lbs. per sq. in. is to be safely developed in the steel without the rod slipping through or away from the concrete.

Thus in the case of a round steel rod

having a diameter of ½ in. the grip length required is forty times one-half inch, which equals 20 inches. This is illustrated in *Fig.* 20, where a rod is shown as embedded in a block of concrete for the specified length, and with this condition it would be possible to pull on the steel rod with a force equal to 16,000 lbs. per sq. in. of the area of the rod without pulling the latter out of the concrete block or in any way separating the two materials.

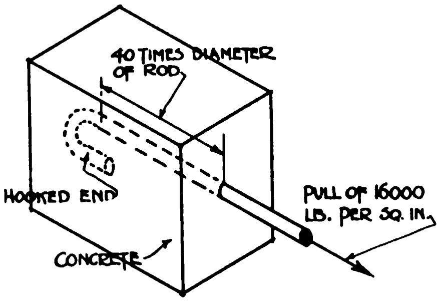


FIG 20

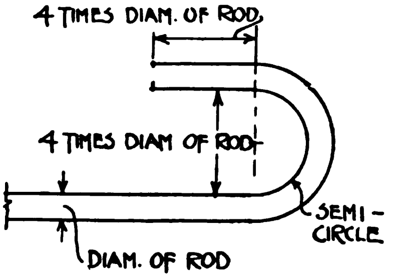


FIG. 21.

As the adhesion of the steel rods to the concrete is so important the foreman will appreciate the necessity of seeing that the reinforcement is not covered with mud or dirt or loose scales of rust due to the rods lying in an exposed position on the site for some long time before use. The rough surface produced by slight rusting is not detrimental but gives a better adhesion than a perfectly smooth surface, but it is absolutely necessary to brush off any loose scales, with a wire brush as these will otherwise form a skin between the actual rod and the concrete and the adhesion will be spoilt.

The value of the adhesion can be realised when it is pointed out that several types of rods are made which have projections or indentations on the surface especially to ensure a good grip on the concrete. These rods are sometimes described as " deformed " bars and they are stated to have a mechanical bond with the concrete. It is quite obvious that there would be no market for these special types of reinforcement if the adhesion was not an important matter.

A good adhesion is dependent on clean steel and good dense concrete, and both these are attainable by careful supervision of the work. Where the ends of the rods are not hooked but anchored by other means the grip length must be increased to at least sixty-seven times the diameter of the rod, which means that in the case of a round steel bar having a diameter of one-half inch the grip length must be at least 33½ in. in order safely to develop the strength. Generally speaking, however, hooked ends will be employed, and as these are usually bent on the site it is necessary to point out the correct method of forming them. The inner diameter of the curve must be equal to at least four times the diameter of the rod, and the length of the straight piece beyond the end of the curve must be at least equal to four times the diameter of the rod. This is shown in *Fig.* 21. If the rod, however, is hooked over another main reinforcing rod the inner diameter of the hook may be equal to the size of this rod in order to fit.

(*To be continued.*)

NEW QUAY WALL AT PORTSMOUTH.

For the new reinforced concrete work in connection with the widening of the Camber, the Portsmouth Corporation have decided to adopt the system of quay wall construction developed by Mr. R. N. Stroyer, M.I.Mech.E., examples of which have been described on various occasions in this journal. The contractors are Messrs. Frank Bevis, Ltd., of Portsmouth.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s. d.
Best Washed Sand	per yard	16 0
Clean Shingle, ¾ in. mesh	,,	14 0
,, ,, ½ in. mesh	,,	15 0
Best British Portland Cement	per ton	58*s.* to 63 0
"Ferrocrete" Portland Cement	delivered London 10*s.* per ton extra	

Boarding for Shuttering—		*Sawn.* s. d.	*Wrot.* s. d.
1 in.	per square	23 6	27 6
1¼ in.	,,	29 6	33 6
1½ in.	,,	35 6	41 0

Sawn Timber for Struts and Supports—	
3 in. by 4 in.	from £24 per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £23 ,, ,,

Mild Steel Rods for Reinforcement—		s. d.
⅝ in. to 2⅞ in. Rounds	per cwt.	13 0
9/16 in. to ½ in. Rounds	,,	13 6
⅜ in. Rounds	,,	14 6
¼ in. Rounds	,,	15 6

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed with Clean Water in proportion 1 : 2 : 4—

				s. d.
Do.	do.	in foundation	per yard cube	48 6
Do.	do.	in columns	,, ,,	53 6
Do.	do.	in beams	,, ,,	53 6
Do.	do.	in floor slabs 4 in. thick	per yard super	5 8
Do.	do.	in floor slabs 6 in. thick	,, ,,	8 5
Do.	do.	in floor slabs 9 in. thick	,, ,,	12 3
Do.	do.	in walls 6 in. thick	,, ,,	8 8

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s. d.
From ¼ in. to ⅜ in.	per cwt.	25 0
,, 9/16 in. to ½ in.	,,	24 0
,, ⅝ in. to 2⅞ in.	,,	23 0

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.*

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.*

Shuttering—		s. d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59 0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55 0
Do. do. in small quantities	per ft. super	0 10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0 11½
Do. do. as last, in narrow widths	,, ,,	1 1½
Do. do. to sides and soffits of beams average 9 in. by 12 in.	,, ,,	1 1½
Do. do. as last, in narrow widths	,, ,,	1 3½
Raking, cutting, and waste to shuttering	per ft. run	0 3
Labour, splay on ditto	,, ,,	0 2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0 3

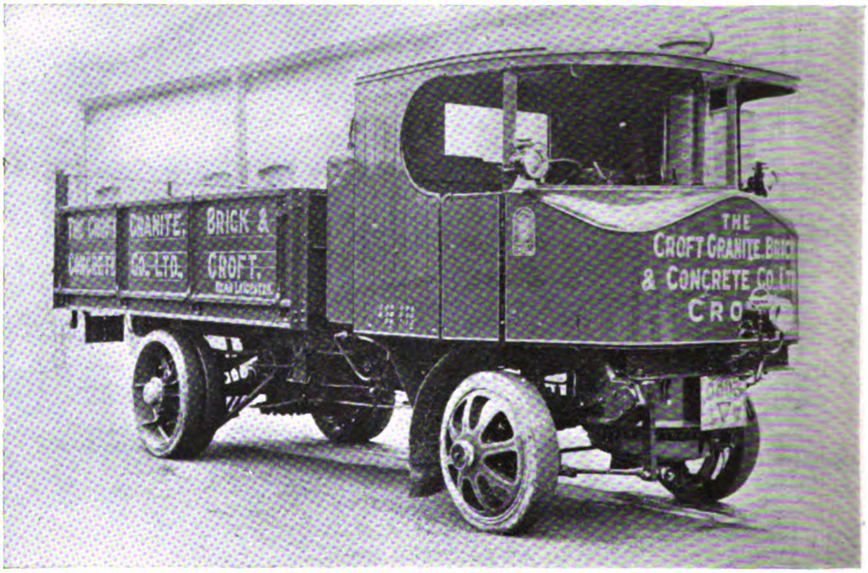
WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Labourers on building works, 1/4½; Operators on concrete mixers and hoists, 1/5½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

ROAD TRANSPORT.

WE recently had an opportunity of seeing a demonstration of a new roadless tractor shortly to be put on the market by the Sentinel Waggon Works (1920), Ltd., of Shrewsbury. This tractor, which has extraordinary pulling powers, is fitted with tracks on similar lines to "tanks," and the demonstration proved its ability to climb steep hills and to travel over rough ground as well as on hard roads; the machine, in fact, seems to possess all the powers of a "tank" for passing over or through obstacles, with the difference that not once was it brought to a standstill through becoming stuck in the mud.

Of more interest to the readers of this journal, however, are the well-known "Sentinel" and "Super-Sentinel" road waggons, made by this firm, who claim to be responsible for over 50 per cent. of the world's production of steam waggons. Their great hauling capacity, which ranges from 4 to 12 tons, makes them particularly suitable for transporting such heavy materials as sand and aggregate, and they are becoming increasingly popular for this purpose. On the basis of the life of the "Sentinel" waggons which have been in use for so many years, the makers anticipate that the life of a "Super-Sentinel" should be over 20 years, and the new design makes it possible for them to run on less water, less fuel and less oil. The wear and tear on tyres is also considerably reduced, and many points of wear in the engine and transmission have been eliminated altogether.



A "SENTINEL" WAGGON.

The waggons are fitted with different types of body to suit the requirements of the purchaser, including flat trucks, drop side and ends, slatted sides, covered vans, transferable bodies which may be lifted from the chassis with the load, and with end tipping, side tipping and three-way tipping bodies. They may also be had fitted with an overhead runway or a jib crane.

TRADE NOTE.

The County Borough of St. Helens (Lancs.) have placed a contract with Messrs. David Weston & Company, Ltd., of Blackfriars House, New Bridge Street, E.C.4, for "Concretus" double-layer reinforcement for the reconstruction of a main thoroughfare with concrete surface. The road will be laid in alternate bays, and the entire work is under the direction of Mr. A. W. Bradley, M.Inst.C.E., Borough Engineer.

PROSPECTIVE NEW CONCRETE WORK.

Alfreton.—*Houses.*—The U.D.C. has applied for sanction to erect 120 houses.

Amble.—*Reservoir.*—The U.D.C. has applied to the M. H. for sanction to borrow £6,000 for the construction of a reservoir.

Ashwick. — *Reservoir.* — The Shepton Mallet R.D.C. proposes to erect a reservoir for the Ashwick, Binegar, and Emborough water supply.

Aylesbury.—*Houses.*—The T.C. proposes to erect 64 houses.

Bedlingtonshire. — *Houses.* — The U.D.C. has applied to the M.H. for a loan of £34,200 for the erection of 76 houses at Sleekburn.

Bilston.—*Houses.*—The U.D.C. is negotiating for the purchase of ground for the erection of 600 houses.

Bolton-on-Dearne. — *Houses.* — The U.D.C. has applied for permission to build 500 houses.

Bristol.—*Concrete Houses.*—The Corporation proposes to build 270 concrete houses.

Camberley. — *Sewage Works.* — The U.D.C. has applied to the M.H. for sanction to borrow £9,450 for sewage disposal works.

Camborne. — *Sewage Works.* — The U.D.C. has applied to the M.H. for sanction to borrow £56,500 for the construction of sewage disposal works.

Carlisle. — *Houses.* — The T.C. has applied to the M.H. for sanction to borrow £128,000 for the construction of 880 houses.

Derby.—*Houses.*—The T.C. has applied to the M.H. for permission to erect 239 houses.

Downham (Essex). — *Houses.* — The L.C.C. has a scheme in hand for the construction of 2,000 houses.

Garstang.—*Road.*—The R.D.C. is considering the question of constructing a loop road at a cost of £96,000.

Harrogate.—*Houses.*—The T.C. is considering a scheme for the erection of 200 houses on the Ripon Road Farm.

Herne Bay.—*Landing Stage.*—The U.D.C. is considering the extension of the pier landing stage on the Hennebique system, estimated to cost £5,000.

Hove.—*Houses.*—The T.C. is considering the question of erecting 164 houses on the Shoreham Road site.

Lancaster.—*Houses.*—The Corporation proposes to construct 250 houses on the Bulk estate.

Liverpool. — *Concrete Houses.* — The Corporation proposes to erect 5,000 concrete houses.

Milnsbridge.—*Sewage Works.*—The U.D.C. has applied to the M.H. for a grant of £33,500 for the extension of the sewage works at Johnny Moor Hill.

Nottingham. — *Bridge.* — The Notts. C.C. proposes to replace the Gunthorpe Toll Bridge with a reinforced concrete bridge, estimated to cost £125,000

Ossett.—*Road.*—The T.C. is considering the question of laying a road from Market Place to Leeds Road.

Penarth.—*Pier.*—The U.D.C. proposes to reconstruct the pier in concrete.

Plymouth. — *Concrete Houses.* — The T.C. is considering the question of erecting 800 concrete cottages.

Ryde.—*Paving.*—The T.C. proposes to repave the footpath of Union Street in concrete.

Scunthorpe. — *Houses.* — The Scunthorpe U.D.C. proposes to erect 30 houses on the Crosby estate.

Sedgefield. — *Houses.* — The R.D.C. has applied to the M.H. for permission to erect 300 houses.

Sedgeley. — *Sewage Works.* — The U.D.C. has applied for permission to borrow £76,000 for sewage works at Lower Gornal.

Selby.—*Concrete Bridge.*—The West Riding C.C. proposes to erect a reinforced concrete bridge over the Aire and Calder Canal at Selby.

Shrewsbury. — *Concrete Road.* — The Shropshire C.C. proposes to lay a concrete road at Shrewsbury, at an estimated cost of £3,490.

Skipton.—*Houses.*—The U.D.C. has applied for the approval of the M.H. for the erection of 100 houses.

Sowerby Bridge. — *Houses.* — The U.D.C. has applied to the M.H. for sanction to erect 58 houses.

Stoke-on-Trent. — *Houses.* — The Housing Committee recommends the erection of 500 houses.

Stonehaven.—*Bridge.*—The R.D.C. has a scheme on hand for the construction of a reinforced concrete bridge at Kirton, estimated to cost £10,350.

Sunderland.—*Houses.*—The T.C. is considering a scheme for building 42 houses in Newcastle Road.

Swinton.—*Houses.*—The U.D.C. has applied for a grant in connection with the construction of 57 houses.

Tanfield.—*Houses.*—The U.D.C. is negotiating for the purchase of land for building 30 houses.

Treharris.—*Houses.*—The Merthyr T.C. proposes to erect 126 houses at Treharris.

York.—*Retaining Wall.*—The City Council is considering the construction of a concrete retaining wall to the river at Foss Islands Road.

TENDERS ACCEPTED.

Backford. — *Bridge.* — The Cheshire C.C. has accepted the tender of Mr. W. H. Brocklesby, Birkenhead, at £2,527 19*s.*, for reinforced concrete work in connection with the reconstruction of the canal bridge at Backford.

Berwick.—*Bridge.*—The T.C. has accepted the tender of Messrs. Holloway Bros., Ltd., London, at £122,900, for the construction of a reinforced concrete bridge over the Tweed.

Bradford.—*Concrete Cottages.*—The T.C. has accepted the tender of Messrs. H. Boot & Son (London), Ltd., for the erection of 700 concrete cottages.

Bridlington.—*Reservoir.*—The B.C. has accepted the tender of Messrs. Squires & Son, at £1,578 13*s.*, for the construction of concrete columns, beams, and walls in connection with the covering of the reservoir at the Higher Waterworks; and also the tender of the Pre-Cast Concrete Co., at £2,669, for the supply of hollow-cast flooring for the covering of the reservoir.

Caerphilly.—*Bridge.*—The D.C. has accepted the tender of Mr. Watkin Williams, Caerphilly, at £350, for the erection of a reinforced concrete footbridge over the river Rhymney.

Cheltenham.—*Tanks.*—The T.C. has accepted the tender of Mr. W. Drew, at £3,788 10*s.* 4*d.*, for the construction of reinforced concrete tanks, meter house, etc.

Dorking. — *Sewage Works.* — The R.D.C. has accepted the tender of Messrs. A. Hardy & Co., Woking, at £12,281, for the construction of sewage disposal works.

Portsmouth. — *Concrete Duct.* — The Corporation has accepted the tender of Mr. D. T. Jackson, Barking, at £5,627 3*s.* 8*d.*, for the construction of a reinforced concrete duct.

Sheffield. — *Concrete Houses.*—The T.C. has accepted the tender of Messrs. H. Boot & Son (London), Ltd., for the construction of 1,000 concrete houses.

Southend-on-Sea. — *Platforms.* — The T.C. has accepted the tender of Mr. W. J.Cearns, at £2,328, for erecting concrete platforms.

Yeovil.—*Houses.*—The T.C. has accepted the tender of Messrs. F. James & Sons, Bath, at £23,437, for the erection of 50 concrete houses.

RECENT PATENT APPLICATIONS.

220677.—J. R. Garrow, G. O. Case and Novocretes, Ltd.: Treatment of wood or similar bodies to be used as an aggregate with, or as a reinforcement for, calcareous cement.

220717.—F. Emperger and A. Umlauf: Concrete or the like pipes.

220789.—A. E. White (Lock Joint Pipe Co.): Method of and apparatus for making centrifugally moulded concrete pipes.

220888.—E. J. Farrell and G. M. Callender & Co., Ltd.: Concrete and like roadways.

Change of Address.

Mr. R. N. Stroyer, M.I.Mech.E., consulting engineer in reinforced concrete, has removed to No. 224, Abbey House, Victoria Street, London, S.W.1.

Messrs. The Cement Marketing Company, Ltd., The Associated Portland Cement Manufacturers, Ltd., the British Portland Cement Manufacturers, Ltd., the Wouldham Cement Co., Ltd., Martin, Earle & Co., Ltd., and associated companies have removed to Portland House, Tothill Street, Westminster, S.W.1 (telephone, Victoria 9880). The British Portland Cement Research Association is now also at the above address.

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REINFORCED CONCRETE ENGINEERS AND ROAD SPECIALISTS

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INTERLOCKED DOUBLE-LAYER,
DOUBLE-LAYER with VERTICAL SHEAR MEMBERS
and
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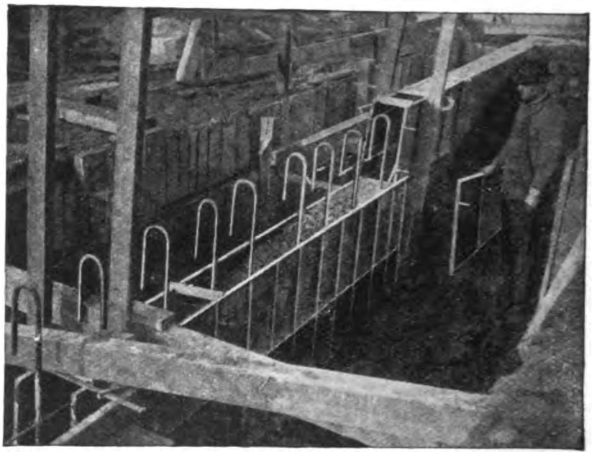
Telephone: Victoria 9616.   Telegrams: "Pyraminwal, Sowest, London."

Some recent **LONDON Concrete Work** with

METAFORMS

The work shown in this photo was carried out under most difficult conditions. The retaining wall seen is emerging from the mass of timber braces and struts which were necessary to hold up the excavated ground which was on the move owing to very heavy rains. Yet a splendid job was obtained!



As will be seen the METAFORMS produced a true plumb wall quite unaided by supports and the finished face of the wall required no rendering. It is work of this type which brings out the true value of METAFORMS.

Part of a Retaining Wall at Streatham, S.W.
Contractors: Messrs. HOLLIDAY & GREENWOOD, Ltd., Battersea, S.W.

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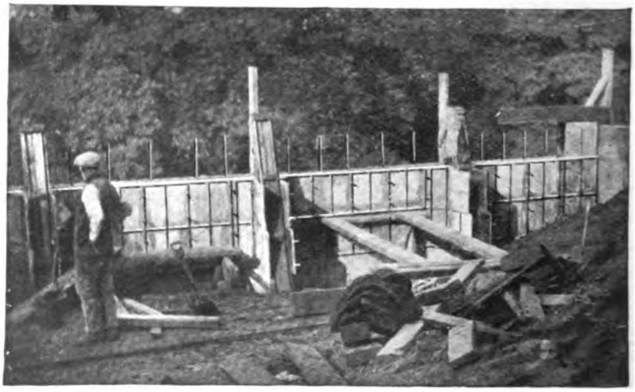

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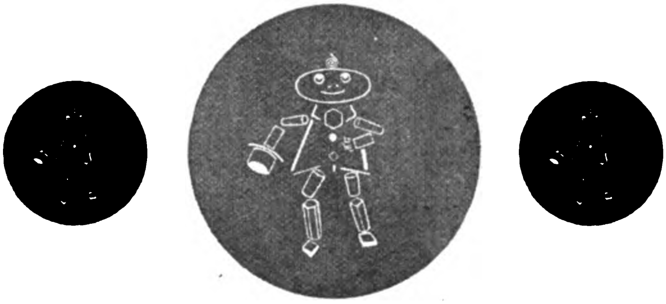

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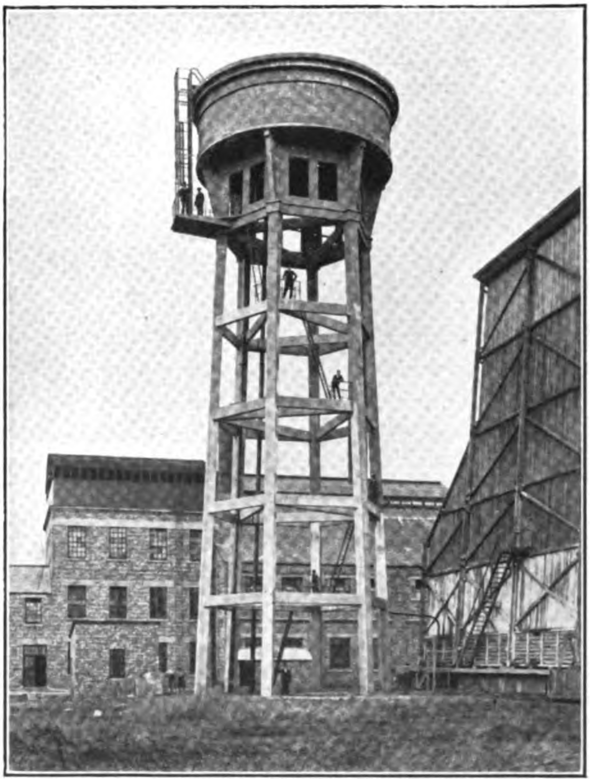

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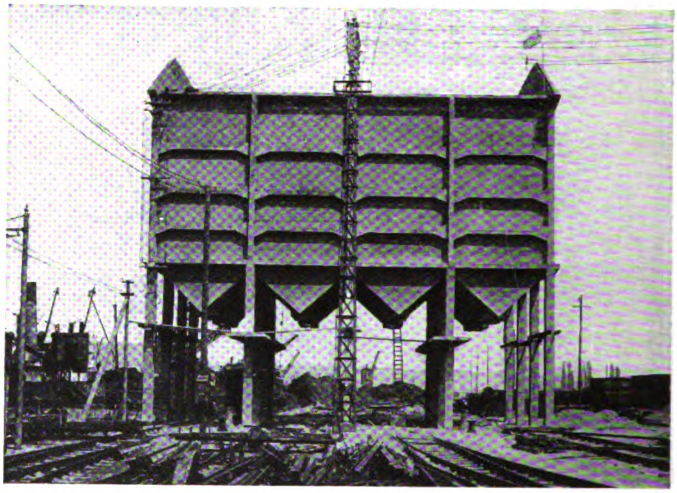

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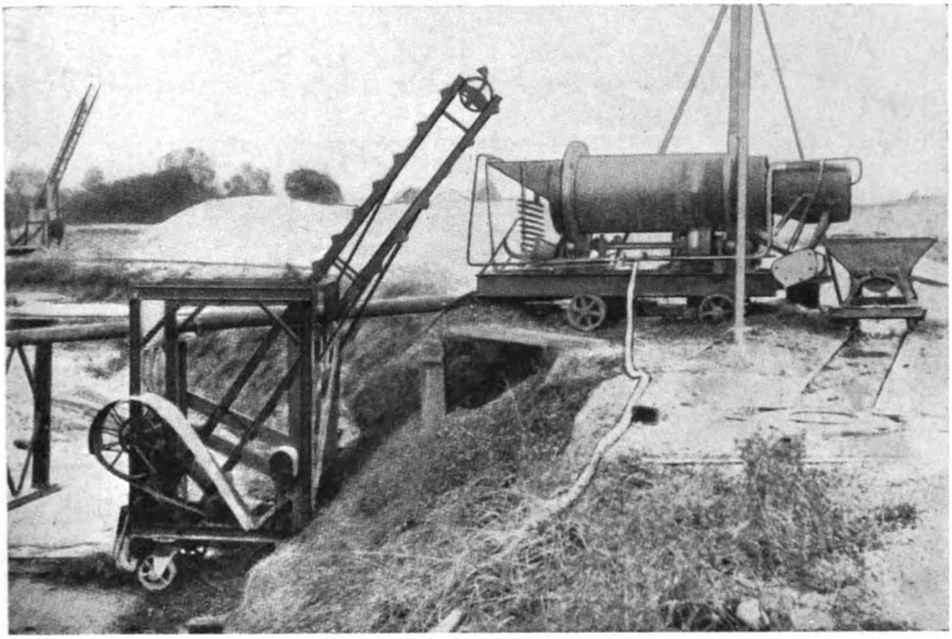

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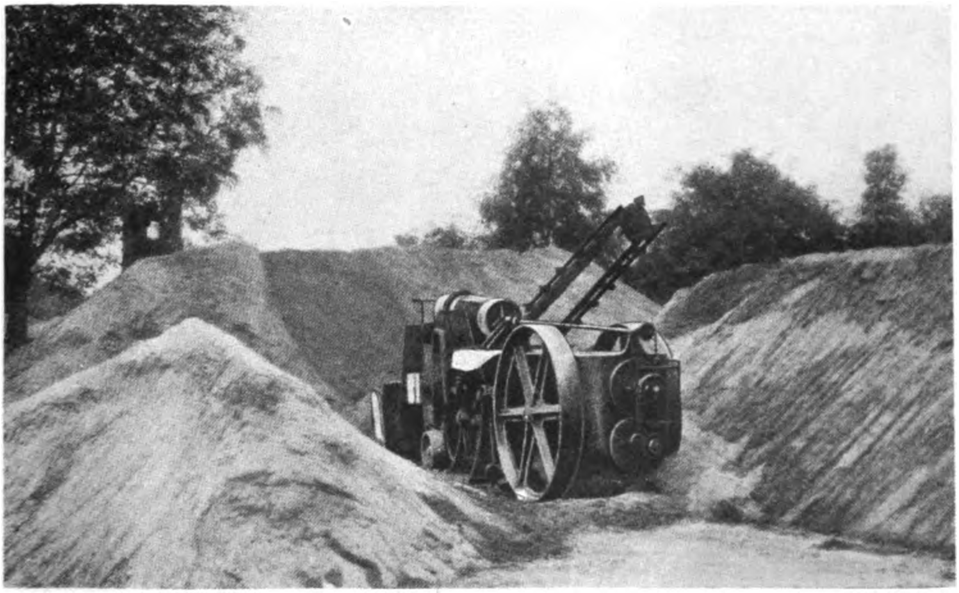

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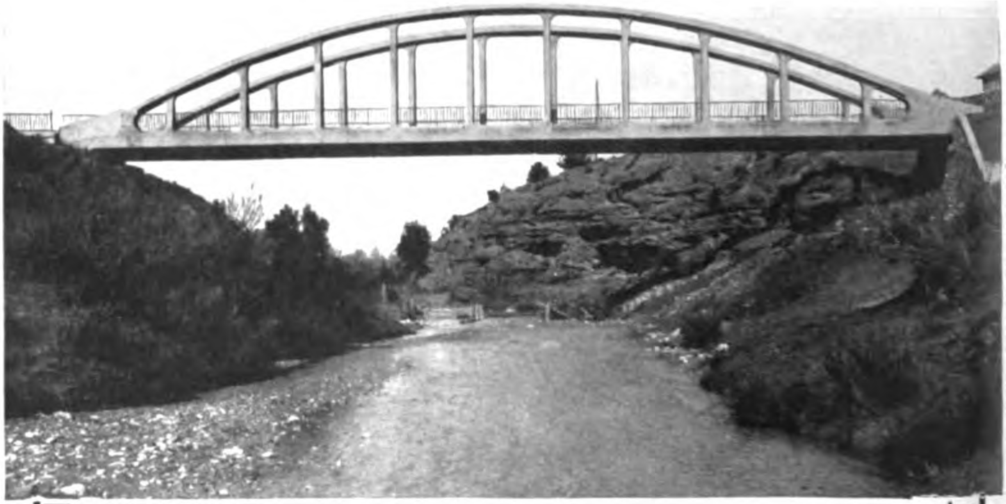

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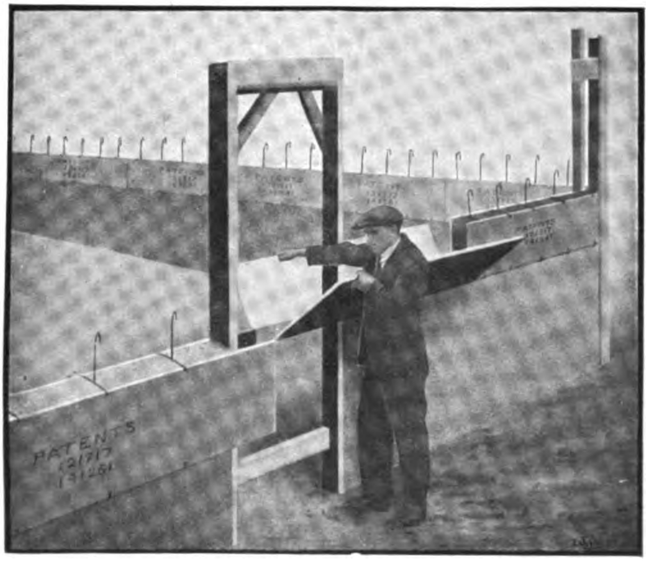

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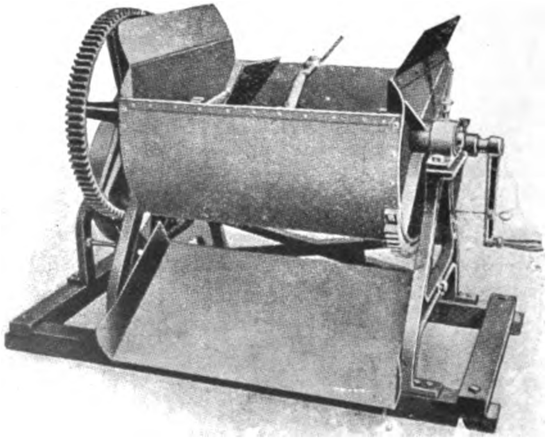

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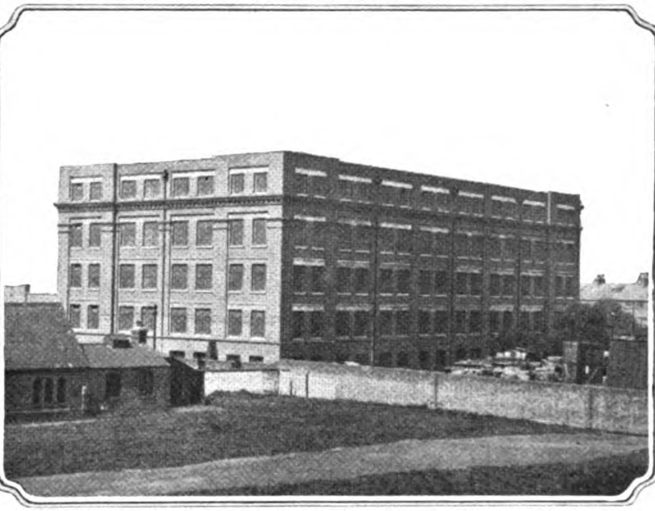

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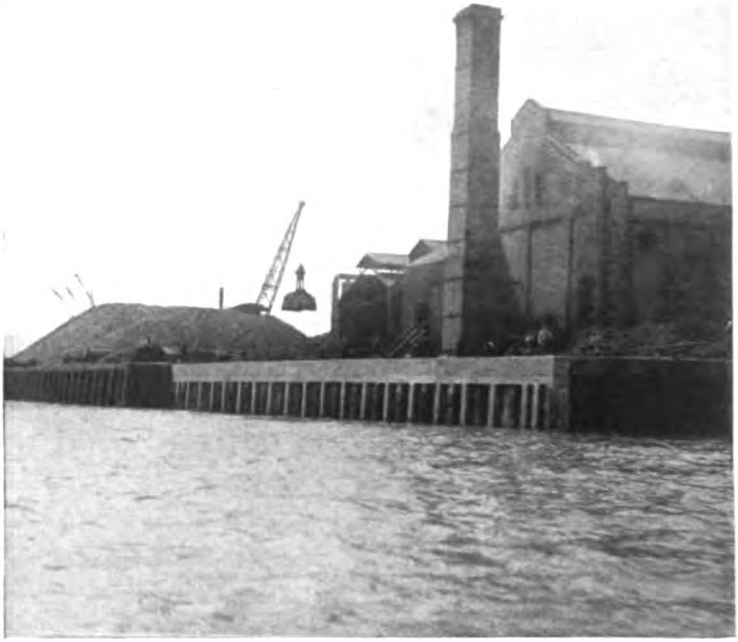

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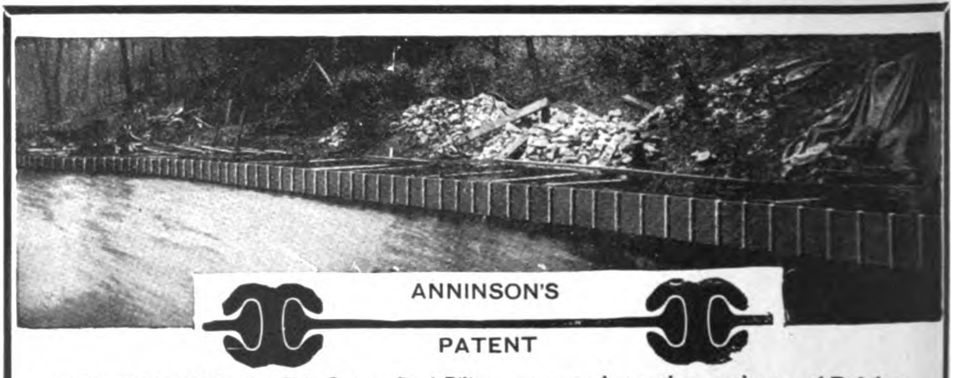

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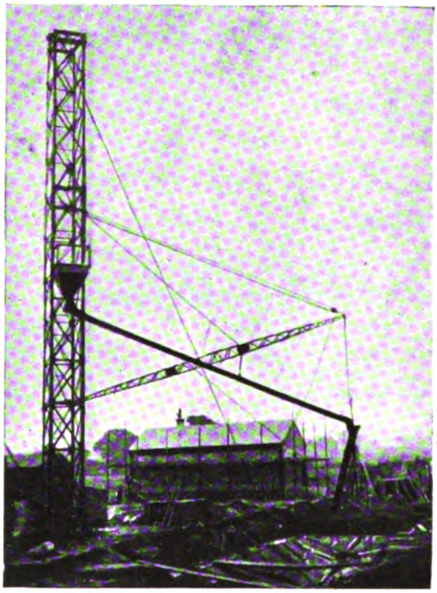

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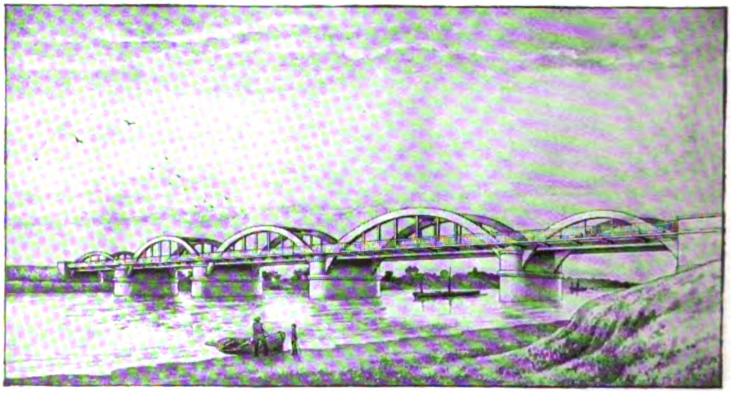

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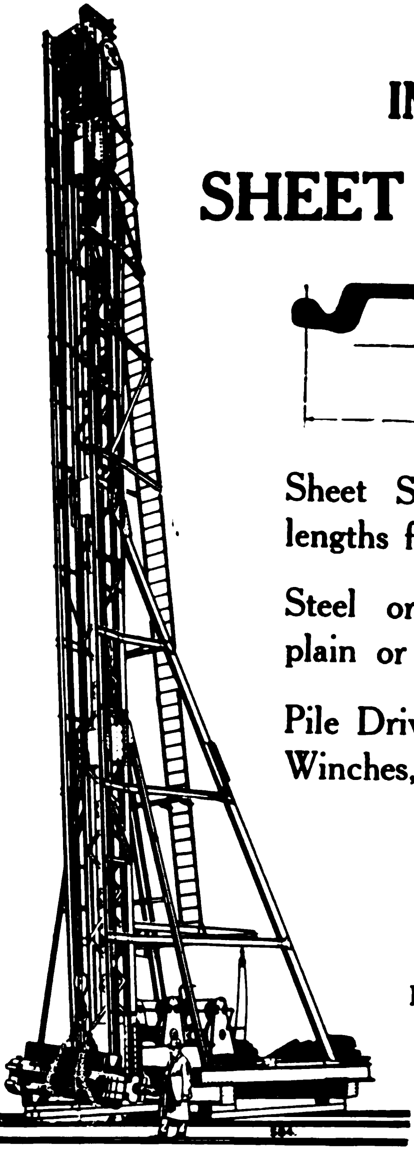

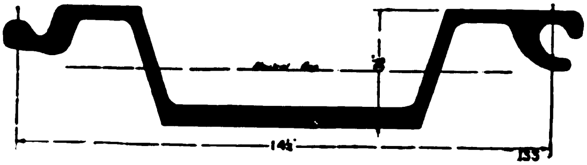

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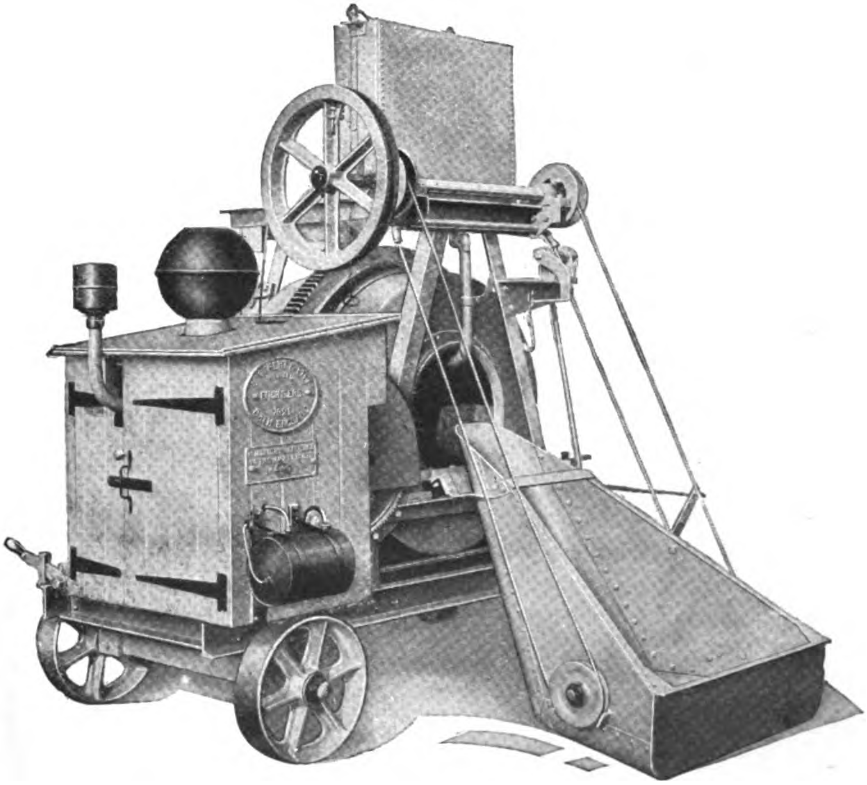

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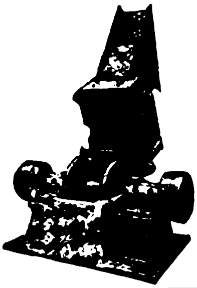

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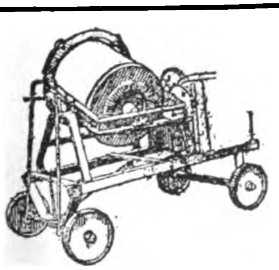

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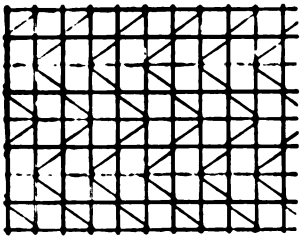

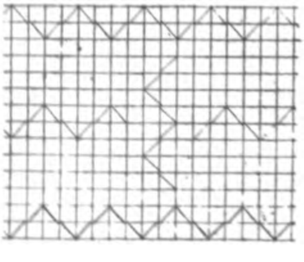

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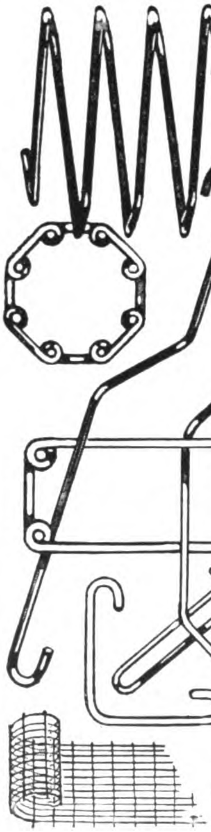

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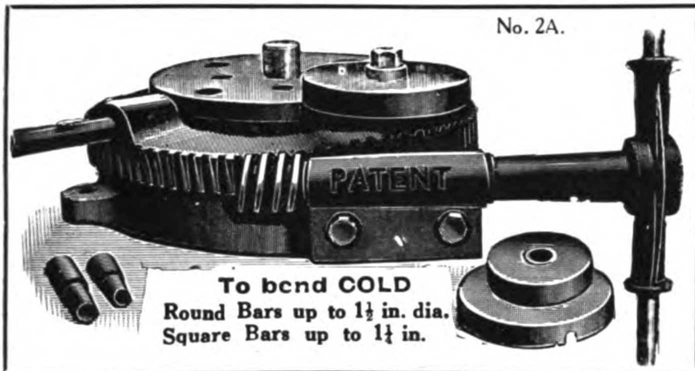

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